A Multi-criteria Analysis of Adapting the Tiv Traditional Hut to Climate Change: A Case Study of the Kanshio Community, Makurdi, Benue State, Nigeria.

By

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30 May 2020

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Declaration

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Dedication

I dedicate this thesis to God without whom this thesis would have been impossible. Also, to my husband and children Katlynn Adaora Alianater, Jason Jidenna Kater and Kayla Chimsonari Avaana who are part of the upcoming generations that will have to live with the impacts of the actions or inactions, of societies today.

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Abstract

There has been significant research on the impact of climate change and possible strategies to reduce and adapt to these impacts. However, the role of the public response remains poorly theorized and under-studied. This thesis reviews how the built environments in the rural tropical communities of Sub-Saharan Africa are adapting to climate change. The research included an extensive study on present constraints to adapting the traditional huts in the '*Kanshio*' community of Benue State, Nigeria.

The thesis aims to understand the perception and sustainable adaptation strategies of '*kanshio'* rural households toward the adverse effects of climate change. A mixed-method approach was adopted involving questionnaires, interviews, focus group discussion and informal discussion. The study examined perceived impacts of climate change on the current method of building and the adaptation strategies of households to the events of climate change impacts. Data analysis was carried out using analytical software, such as Graph Prism and Microsoft Excel.

Although the built environment in the tropical rural community is particularly vulnerable to climate change, such as extreme temperature, droughts, desertification, flooding and cyclones, they are the most poorly adapted and investigated. The study finds that economic reasons were mostly responsible for the lack of preparedness and adaptation. An additional finding was that, preserving the culture of ancient traditional architecture as an approach to improving building energy performance, room temperatures and flood impacts are worthwhile. Creating awareness can help improve building performance as part of public response.

Keywords: *Adaptation, Cost, Climate change, Impact, Communities, Flood, Temperature, Ate.*

CHAPTER 1 : INTRODUCTION

1.1 Background of study

It is no longer arguable that the twin challenges of global warming and climate change (CC) are the most significant environmental issues currently confronting the world. Climate-related disasters such as the July 2019 1.5 metre height of ice after hours of high temperature in the Mexican city of Guadalajara (BBC, 2019), January 2017 intense rain in California after a long-standing drought triggered flooding and mudslides which forced over 200,000 people to vacate their homes and caused an estimated $1.5 billion in property and infrastructure damage (Ivanovich, 2018). In the same year, Europe's most sustained extreme heat event since the deadly 2003 heat wave, recorded 1,050 deaths. Heat waves sizzled in Australia setting a record in which New South Wales and Southern Queensland reached its highest ever overnight minimum temperature, for December. Sydney also experienced the hottest night in January since weather records began in the mid-1800. That same year, Somalia experienced drought that caused a staggering 6.2 million people, half of Somalia's population, to require urgent humanitarian aid, reflecting the world its continuous exposure to destructive and persistent CC (Ivanovich, 2018).

Although CC is fundamentally a global issue, its impacts are not projected to be felt equally across the planet. Prospects and constraints are unevenly distributed among global regions, communities, sectors, ecological systems and species as well as across different time periods (Klein *et al.* 2014) (Figure 1.1). There remains substantial uncertainty on the rate and behaviour of these changes (Christensen *et al.* 2007). For instance, Intergovernmental Panel on Climate Change (IPCC) (2014) reported that CC impacts are likely to result in extreme heat-waves, droughts, desertification, floods, cyclones, wildfires etc., in the tropics.

The report further revealed considerable vulnerability and exposure of Sub-Saharan Africa and South East Asia (Figure 1.1) to the projected adverse impact events. In addition to this, it anticipates that the frequency of other climate-related extreme events such as alteration of ecosystems, disruption of food production and water supply, damage to infrastructure, settlements, morbidity and mortality will increase in these regions. Hence, timely and local adaptation to unfamiliar severity and occurrences of hazards under a changing climate becomes imperative (Debels *et al.* 2009). Harasi *et al.* (2011) suggested that for countries at all levels of development, these impacts are consistent with a significant lack of preparedness for current climate variability globally. The Environmental Protection Agency (EPA) (2011) further suggested that, in addition to the regional variability of impacts, the scenario is likely to be more complicated by the sectorial variability of CC impact, even with contiguous climatic regions.

Bryan *et al.* (2013) argued that in Africa, the agricultural sector is particularly expected to be adversely affected. This is because agricultural production in Africa, unlike other regions of the world, remains heavily reliant on natural climatic occurrences, such as weather and soil conditions. Adaptation of the agricultural sector is therefore imperative to protect the livelihoods of the poor and to ensure food security. Parenti (2011), on the other hand, argued that many developing countries do not have the ability, such as social infrastructure in place to withstand the anticipated burden on the natural environment that could occur as a result of CC. Even worse, abrupt CC could make adaptation extremely difficult, even for the most developed regions of the world.

Figure 1.1. Uneven distribution of climate change impact, (source*:* Environmental Protection Agency, 2011).

The IPCC's Third Assessment (IPCC, 2001b) assessed the capacity of the world to cope with and adapt to the inevitable impacts that CC will bring. It found that the impacts of CC are unevenly distributed. Research and speculation on people's exposure ratio and how they are coping has been growing at a rapid rate. According to the United Nations Framework Convention on CC (UNFCCC) (2006), the people who will be exposed to the worst impacts are the ones least able to cope with the associated risks. This aspect of coping ability has not been given much attention. Conway (2009) pointed out that, given that over 70% of people in Sub-Saharan Africa live in rural areas, their livelihoods will be most at risk from CC impacts. This situation becomes even worse, given that about a third of the African population already experience severe periodic famines caused by civil unrest, poor governance and production capacity inadequacies.

Nigeria is among the most vulnerable to the confrontational effects of CC. It is poverty-stricken and weak infrastructure has been a long-standing issue in Nigeria, which has made her capacity to adapt to CC and disasters very low. Olurunfemi (2009) reported that Nigeria and her people are expected to be most affected by CC through sea-level rise along its coastline, increased desertification, soil erosion, flood disasters and general land degradation. Although Nigeria has engaged with the UNFCCC, much still needs to be done to develop local responsiveness in a sustainable fashion, developing data availability and coping ability. Studies of community adaptation in Nigeria are rarely available.

Considering the uneven growth of sustainability services across the world and recognising the expected growth in sustainability of the built environment in developing countries, this paper aims to understand the perception and sustainable adaptation strategies of *kanshio* rural households to the adverse effects of CC impacts. Through survey, questionnaire, interviews, focus group discussion and informal discussion, this study examines:

- Perceived impacts of CC on the current method of building.
- The adaptation strategies of households to the events of CC impacts.

The findings of the study could provide context-specific inputs for policy-makers and generate useful insights for comprehending the underlying factors for effective and sustainable adaptation for the community. The study is divided into four parts: the introduction, which states the purpose and relevance of study, the second part of the thesis will explore the material and methods used in the study and the third part will discuss results and findings on strategies and constraints of CC adaptation in the study area. Finally, the conclusion will give an overview of the key findings of the research and possible recommendations.

1.2 Causes of climate change (CC)

Although there are disagreements on the causes of CC, IPCC assessments conclude that current changes in climate are primarily the result of human activities. There is contention over the scientific methods that point to this conclusion. The diverse proxy sources of evidence and complex computer models used to predict CC are considered by some to be inaccurate. Hansen *et al*. (2016) and Lindzen (1997) are some of the early disputers. Finally, even if the influence of human activities on climate is accepted, some scientists point out that those global feedback mechanisms may counteract the increased input of greenhouse gases into the atmosphere, eventually stabilizing the climate (Pearce, 2005). These arguments call into question the fundamental assumptions behind international action to reduce carbon emissions by suggesting that current climatic changes are natural, cyclical and not disastrous.

There has been much interest recently in the concept of adaptation and its relevance to minimizing the causes of CC, which are attributed directly or indirectly to human activities, such as deforestation, industrialization, waste production, disposal and transportation among others and which are usually observed over time (Mings, 2014). This is presently one of the most serious threats to sustainable development, both in urban and rural environments. These events are altered by environmental forces and processes which give the extreme differences in temperatures. Lang *et al.* (2016) suggested that the anticipated adverse effects or impact are equally attributable to natural activities which impact on the environment and human health, food security, economic activities, natural resources, physical infrastructure and agriculture which is considered the most vulnerable (Figure 1.2) CC also refers to the long-term significant change in the 'average weather' that a given region experiences. Climate variability refers to the variation in the mean state and other statistics of climate on all temporal and spatial scales beyond that of individual weather events IPCC (1992).

Figure 1.2. Sources of CO_2, (source: Mings, 2008)

1.2.1 *Carbon emission*

Tedsen (2013) reported that black carbon particles, which are the result of incomplete combustion of fossil fuels, biofuels and biomass, absorb sunlight and heat in the atmosphere, increasing radiative production and contributing to CC. She concluded by naming black carbon to be a '*major climate warmer, second only to CO_2*' and together with other pollutants that have a similar powerful, but short-lived, warming influence, it is known as a short-lived climate pollutant (SLCP). Figure 1.3 shows a direct black carbon radiative forcing from residential kerosene lighting (W/m^2). Nigeria is highlighted by medium to high severity.

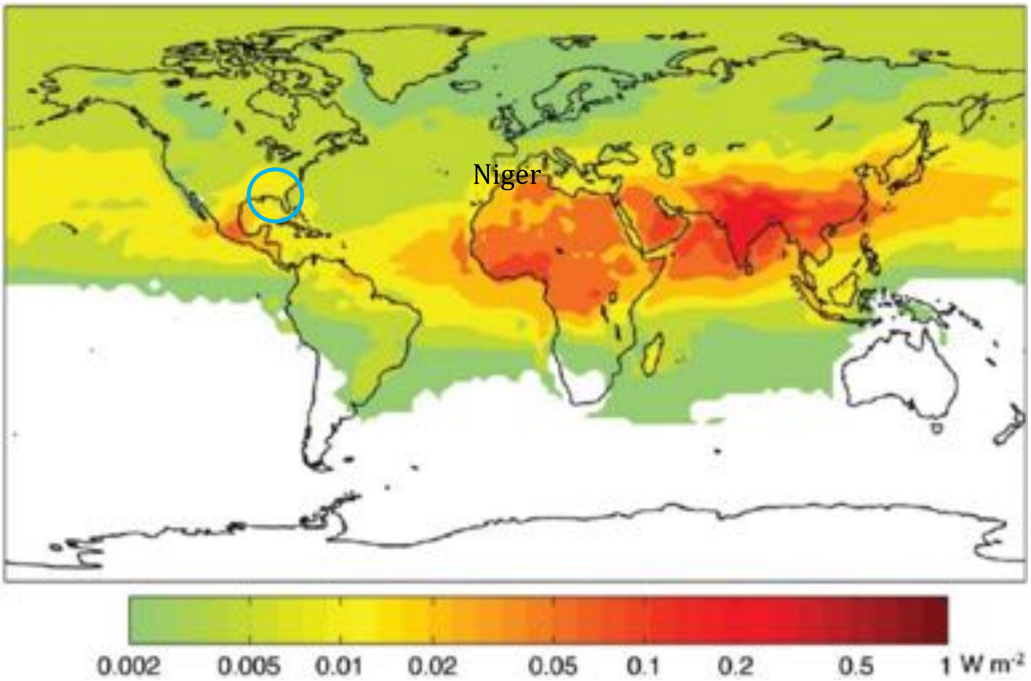


Figure 1.3. Black carbon emission, (source: Tedsen, 2013).

Tedsen (2013) suggested research has revealed kerosene lamps as substantial sources of atmospheric black carbon and that they emit 20 times more than previous estimates, with 7-9% of the fuel burned changed into black carbon particles. She also stated that the resulting climate warming impact is scaled higher than prior calculations. Finally, she adds that while some sources of black carbon emit other non-black particles that may have an offsetting cooling effect. Kerosene lamps emit almost entirely black carbon and CO_2, both of which cause warming. Overall, 270,000 tonnes of black carbon are estimated to be emitted from kerosene lamps worldwide. This has a climate warming nearly equivalent to 240 million tonnes of CO_2, roughly 4.5% of the United States' CO_2 emissions. The warming impact of black carbon emissions from kerosene lamps is at its highest around source regions and reaches 0.5 watts per square metre (Tedsen, 2013).

1.3 Climate change conflicts

In 1988, the Intergovernmental Panel on Climate Change (IPCC) was established by the World Meteorological Organisation and the United Nations Environmental Programme (UNEP) to measure and present current scientific knowledge about CC, its predicted impacts and policy responses. The IPCC's first, second and third assessment Report, published in 1990, 1995 and 2001 respectively, embody the views of the majority of the world's climate scientists and have also involved governmental councils in ensuring the scientific information is presented clearly for policy-makers. The IPCC Report concluded, with near certainty, that there is an apparent human influence on global climate (IPCC, 2001), while uncertainty remains in the scale of climatic change and its specific regional distribution. The Report argued that humans are upsetting the climate, principally through burning fossil fuels which release CO_2, coupled with deforestation and other land use changes. Data from IPCC (2001) show that present levels of CO_2 have not been exceeded for at least the past 420,000 years and that the rate of temperature increase over the past century is exceptional. Furthermore, during the 20th Century, sea levels have risen globally between 0.1-0.2m; ice and snow cover have decreased; and rainfall patterns of have changed (IPCC, 2001).

1.4 Political and cultural responses to climate change

Climate change has developed over the past years as an issue of global political and social significance. The topic was given political acceptance by key figures in the late 1980s (Thatcher, 1988), by bringing together political and scientific representatives in the production of the IPCC report. As a result, Houghton (2004) suggested that scientific agreement has been of importance in inducing politicians and policy-makers to take seriously the problem of global warming and its impacts. The burden of scientific evidence proving the reality of the threat from CC was a prerequisite for government commitments to potentially transform economies and human behaviour (O'Riordan and Rayner, 1991).

1.5 Climate change response in the tropics

In recent years, the study of CC has focused on responses to its inevitable occurrence. One response is through the design of the built environment. To appreciate the tropical response to architectural design in Africa, one needs to consider the core relationship between local building use and the reading of the modern building. Tropical architecture used as a description of modernist architecture in Africa, had its birth in British West Africa, in the Gold Coast (Ghana), Nigeria, Sierra Leone and The Gambia at the end of the Second World War (Uduku 2006).

Corlett (2012) studied CC in the tropics and reported that there has been a rapid shift in opinion in recent years, with the widespread recognition that the climate is already changing at a rate that is relevant to current conservation actions in the tropics. Although greater emphasis on these guidelines is placed on the second objective, the Data Distribution Centre (DDC) provides information supporting both, recognizing that the scenarios underpinning impact and adaptation studies should also be consistent with those assumed for emissions and hence for climate and for other environmental scenarios. Many key parameters, such as population and economic growth, are common to both types of exercise (IPCC, 2007).

Since the mid-1970s the tropics have warmed at a mean rate of 0.26 °C per decade (Malhi and Wright, 2004 in Corlett, 2012). IPCC (2007) developed an elaborate framework with more information for most users of CC projections and a summary for policy-makers. Predictions of temperature increases range from 0.4°C to <2°C warming, with most species able to adapt *in situ* to disastrous forest die-back and mass species extinctions before the end of this century. We need to both narrow this range, through well-targeted research and at the same time, attempt to reduce the likely impacts of high-end CC by pre-emptive conservation planning (Hughes, 2010; Corlett, 2011). A widely applicable example of such planning would be preserving (or restoring) forest continuity along altitudinal gradients and maximizing the opportunity for low-altitude species populations to retreat to cooler refuges in response to warming.

Well before 2100, most of the tropics will be subject to climatic conditions that will be outside the range experienced by any tropical ecosystem on earth for millions of years. This 'new tropic' will undoubtedly be different from the one we are familiar with, but we do not yet know enough to predict how different. One early casualty will surely be the current focus on the preservation and restoration of 20th Century "*baseline conditions*" (Thomas, 2011). The climatic zones of Nigeria are divided into three with case study zone highlighted (Figure 1.4).

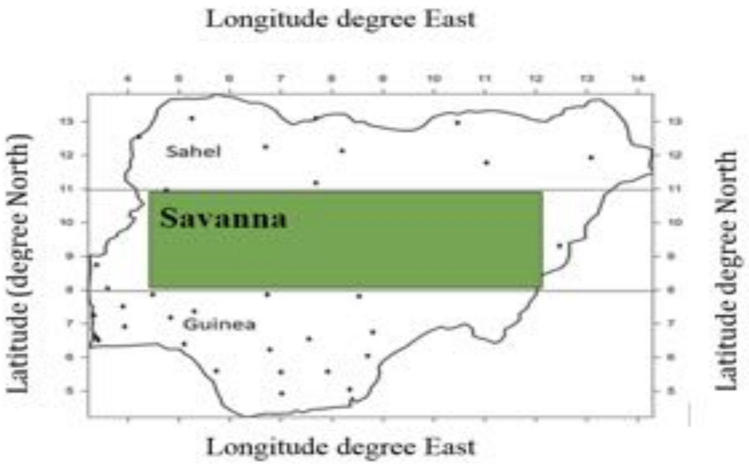


Figure 1.4. Meteorological stations and climatic zone division in Nigeria (adapted from Abiodun and Omotosho, 2007).

Guinea

Ikeja, Oshodi (Agromet), Lagos (Roof), Lagos (Marine), Ibadan, Ijebu-Ode, Abeokuta, Oshogbo, Ondo, Benin, Akure, Warri, Onitsha, Port-Harcourt, Owerri, Enugu, Uyo, Calabar, Ikom and Ogoja.

Savannah

Yelwa, Kaduna, Bauchi, Ilorin, Shaki, Bida, Minna, Abuja, Jos, Ibi, Yola, Iseyin, **Makurdi,** Lokoja.

Sahel

Birni Kebbi, Sokoto, Katsina, Gusau, Zaria, Kano, Nguru, Potiskum, Maiduguri.

Grogg (2012) reported on the October winds ≤200 m per hour and waves 9 m high that wrecked dozens of houses along the coast of Cuba in November 2012, was described by a 12-year-old saying: "*But then the waves rose higher and the wind became stronger, we heard something like the roar of a beast over us. People were crying and I thought my time had come*". To minimize these unexpected occurrences, adaptation should not be treated as an option.

There is now a considerable body of research which suggests that well-thought actions need to be taken to combat the impacts of CC. Olurunfemi (2009) stated that to make informed decisions about CC adaptation, policy-makers will need well-timed and useful information about the possible consequences of CC, people's perceptions of those consequences, available adaptation options and the benefits of slowing the rate of CC. Lack of information and knowledge about CC also means that many Nigerians are reluctant to accept the reality. Furthermore, there is a lack of public policy, government preparedness and commitment to promoting CC adaptation strategies in the country. Given the existing low level of awareness about CC in Nigeria, the way the risk of CC is presented to the public will determine the way the public will react to it. This research proposes that the government encourage and support assistance to the adaptation of individuals, households, community organizations and enterprises. There is a view that the link between CC and its' impacts will stimulate a debate on the scale and nature of the action to be taken by the public. This will lead to creating awareness among communities.

The climate of Nigeria has shown considerable progressive and spatial shifts in its variability and change. (Nigerian Meteorological Agency, (NIMET) (2012). They report that extreme climate and weather events, such as drought, flood, heat waves and ocean surges have become more regular and may be slow but damaging lives and property and negatively impacting on the economy. "*Floods have become a perennial challenge with increasing intensity each year, leaving colossal losses and trauma*" (NIMET, 2012).

This research identified and evaluated key impacts of CC in Benue State, north central Nigeria, a typical tropical rural environment. The project was planned over a period of three years and studied CC impact in Benue State over the major climatic seasons. Besides studying CC adaptation, the research will compare of the social, economic and environmental costs and benefits of adapting a traditional building in the case study area to CC impacts. This will be done by building a prototype and adapting it to the prevailing impacts found in the literature.

Buildings provide an interface between the outdoor environment, which is subject to CC and the indoor environment, which requires preservation within a range that keeps the building occupants comfortable and safe. Uduku (2006) stated that most tropical buildings have been designed to respond to climate, in line with the building research laboratories, such as "*design primers*" Fry and Drew (1954). However, the research analysis carried out to attain the design guidelines in the 1950s was done without significant computing power, which must have been a particularly difficult task. School design was predominantly suited to the passive-cooling approach.

Anthropologists have long established that daily transactional life amongst West Africans occurred outdoors, with buildings only performing the function of shelter from more adverse elements, such as rainfall and as places to sleep at the end of the day. The need for appropriate passive cooling and environmental design could be relevant to those who work in formal sectors but not the masses, who control their own ideal comfort zone. Barbero-Barrera *et al.* (2014) reported that traditional architecture from the opinion of architectural sustainability and in relation to the environment both human and natural, mainly climatic, is the reason for the lifestyle that gives sense to the form of architecture in any community. He suggested that social, economic and environmental adaptations are the three main pillars responsible for effective architectural sustainability. It is important to preserve and maintain as well as to adapt them to technical and functional requirements.

The *Tiv* populace to be one of the major ethnicities in the Middle Benue Valley region of Nigeria. (Ogundele *et al.,* 2007) *Tiv* land stretches from ~6^o30-8^oN and from 8-10^0 E. The region shares a boundary with North-Western Cameroon, a continuation of the Bamenda Highlands. The *Tivs* today live in dispersed compounds or villages within the surrounding plains. The contemporary *Tivs* are fundamentally subsistence farmers, growing crops such as yams, sweet potatoes, beans, guinea-corn, tobacco and maize. Some of these crops are regularly stored for a season and then sold in the rural markets. The monies from this mode of exchange are spent on purchasing other products or services. There is growth in the rate at which *Tiv* agriculture is becoming monitarized as a result of the changing social and economic challenges, as well as aspirations of the people (Ogundele *et al.* 2007). They also mentioned that other than farming, the *Tivs* have income from blacksmithing, pottery making and wood carving. A typical *Tiv* compound comprises storeroom/barn architecture, alongside technology which is very complex in scope and character. They are tied to the overall strings of the people's way of life and kinship. The design, construction and usage of storerooms are rooted very firmly in sharing, caring and cooperation among the *Tivs*. A basic picture of an African traditional hut is shown in Figure 1.5. The responses to the impacts of CC are mitigation and adaptation.

Figure 1.5. A traditional African hut, (source*:* Jev, 2009).

1.6 Mitigation and adaptation

1.6.1 *Adaptation*

Adaptation is important in reducing the damage and taking advantage of new opportunities in the light of the rapid CC already occurring and the expected impacts in the future (Ford *et al.,* 2007). Ogungbenro and Morakinyo (2014) defined adaptation as the manner in which people update their expectations of CC in response to unusual weather patterns. Similarly, IPCC (2007) and Melillo (2015) referred to adaptation to CC as actions that helps individuals, communities and governments prepare and adjust to changing climatic conditions, or their impacts in order to reduce harm and damage.

The UK House of Commons Environmental Audit Committee (2010) defined adaption to CC as the process of building the resilience of households, businesses, infrastructure, public services and vulnerable parts of our society. It is about preparing them for the impacts of CC and giving them the best chance to exploit any new opportunities that may arise. It includes:

• Construction of adaptive capacity, creating the information and conditions (regulatory, institutional and managerial) needed to support adaptation.

• Delivering adaptation actions taking precise steps to reduce exposure to threats rising from CC and exploiting opportunities.

Perez and Yohe (2004) suggested that any policy-making method, integrating adaptation to CC, including variability, into regular development planning is a challenge, but because CC can possibly affect all areas of the national economy, adaptation requires both an interdisciplinary approach and cross-sectorial policy analysis. They further imply that careful monitoring and evaluation of implemented adaptation measures can enable users to assess what is working, what is not working and why.

1.6.2 *Types of adaptation*

The Intergovernmental Panel on Climate Change (IPCC, 2007) defined four kinds of adaptation:

1. **Anticipatory (proactive) adaptation**

This type of adaptation takes place before CC impacts occur. Such adaptation is to prevent or minimize these impacts. It weighs up the vulnerability of natural and man-made systems as well as the costs and benefits of action versus inaction. Anticipatory adaption to CC is a planned type of adaptation and it will result in planned adaptation.

2. **Planned adaptation**

This is the adaptation that is the result of a deliberate policy decisions based on an awareness that conditions have changed or are about to change and that action is required to return to maintain or achieve the desired state.

3. **Reactive adaptation**

This type of adaptation takes place after impacts of CC, for instance, when new building regulations follow a severe flood. Reactive adaption is an unplanned type of adaption usually a result of unmanaged natural systems and in this type of adaption, species and communities respond to changed conditions. In these situations, adaptation assessment is essentially equivalent to natural system impact assessment adaptations consciously undertaken by humans, including those in economic sectors, settlements, communities, regions and managed ecosystems. Reactive adaptation takes place as a result of:

- Change in the composition of the ecosystem.
- Change in the length of growing seasons.
- Wetland migration.
- Changes in farm practises.

4. **Autonomous adaptation**

Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. This can affect species in their corridors of protection and may cause animals to become extinct.

1.6.3 *Mitigation*

Perez and Yohe (2004) defined mitigation as a human intervention to reduce the sources or enhance the sinks of greenhouse gases. Examples include using fossil fuel more efficiently for industrial processes or electricity generation, switching to renewable energy (solar energy or wind power), improving the insulation of buildings and expanding forests and other carbon 'sinks' to remove more CO_2 from the atmosphere.

Policies on adaptation and mitigation are made at different governance levels and interrelationships exist within and across each of these levels. The levels range from individual households, farmers and private firms, to national planning agencies and international agreements (Figure 1.6).

1.6.4 *Inter-relationships between adaptation and mitigation*

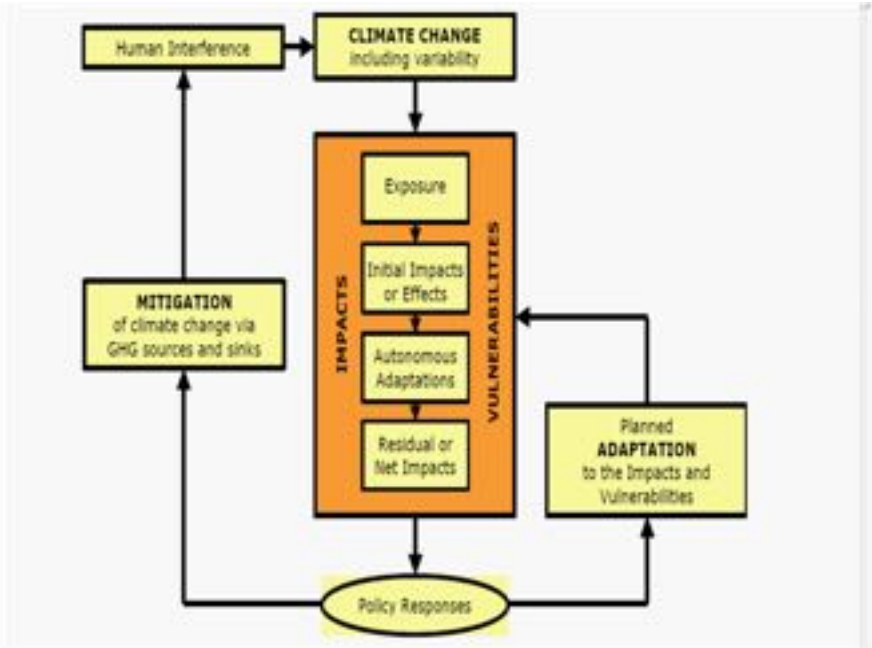


Figure 1.6. Mitigation and adaptation responses to climate change, (source: IPCC, 2001).

Although mitigation initiatives, such as the Kyoto Protocol, national greenhouse gas inventories and global climate models have created a rapidly growing pool of data for measures to mitigate CC impacts, the IPCC Report (2007) asserted that adaptation has not benefited from a similar development in systematic data gathering, upgrading, distribution and application. This gap in data availability and utilization concerning CC adaptation measures has severely limited efforts to maximize the impact of such measures to support sustainable development, particularly in developing countries and small Island developing states which are severely threatened by the effects. Existing and new data on climate must be combined with geographic and economic data to create decision-support tools for adaptation (Figures 1.6 and 1.7.)

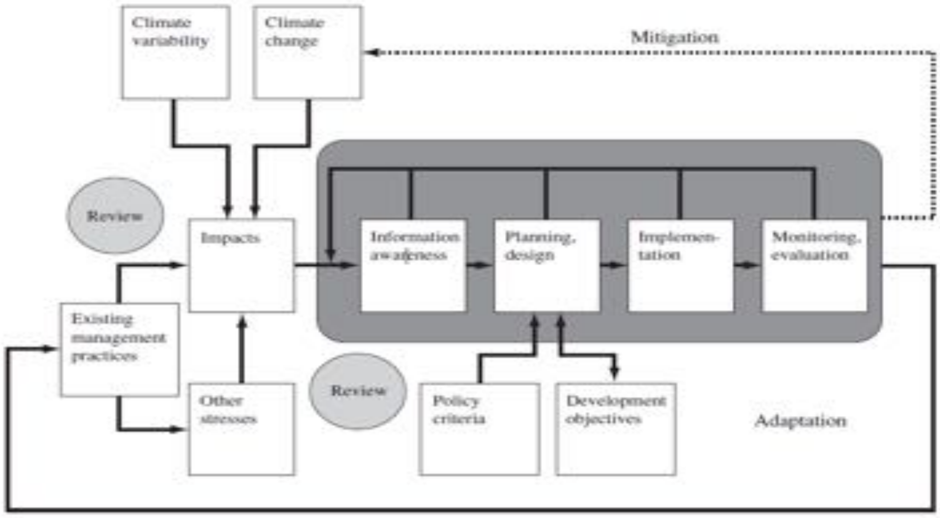


Figure 1.7. Conceptual frameworks on responses to CC variability, (source: Perez and Yohe, 2004).

Deyal *et al.* (2006) emphasized that there is a need for measuring tools to be made widely available to local and regional planners and disaster managers, along with a common framework for data application (Figure 1.6 and 1.7). Examples of required risk management and adaptation decision-support tools include impact scenarios for coastal hazards (storm surge, wave, wind); models for impact on key sectors (such as agriculture, fishing and tourism) land use and wetlands-use determinants; and evacuation and relocation models for affected communities. Data sharing and user education must accompany these tools to ensure equal access for Least Developed Countries (LDCs). Figure 1.8 shows how residents take shelter under the overhang during rain and sunny times.

Figure 1.8. Traditional African hut Botswana, (source*:* Lynda, 2014).

1.6.5 *Inequity in climate change mitigation and adaptation capacities in the rural tropics*

While cc awareness is spreading slowly, its impacts have been felt across Africa, provoking political, economic, psychological and related adversities. The International Council for Science (ICSU) (2007) discussed a record of 18 Sub-Saharan African nations that were flooded almost simultaneously in 2007. Countries such as Uganda, a developing country, pleaded for assistance from the North to contain the flood damage. In their work, "*Natural and Human-Induced Hazards and Disasters in sub-Saharan Africa"*, they show the differential contributions to the triggering CO_2 concentration or accumulation in the atmosphere by most African countries and highlighted the complicated problem that Sub-Saharan African nations face in terms of their weakness in coping with the challenges posed by CC. They state that historically, the trend has been that of socio-economic stagnation in most of Sub-Saharan Africa, including Nigeria and several others overwhelmed by the "Resource Curse". Generally, Sub-Saharan Africa has, until now, been trying to recover from the socio-psychological and economic shocks wrought by colonialism and ongoing globalization.

1.7 Problem statement

There is a paucity of data in the case study area on the level of response to CC adaptation. Preliminary investigation of the literature shows that there are no data measuring the impact of CC or the steps to reducing these impacts. Climate data preserves historical observations and provides the basis for understanding and determining climate variability, predicting extreme climate events and designing adaptation and mitigation strategies. Small-scale, cost-effective projects could enlighten climate adaptation policy and bring about major impacts on the livelihood of local communities, which are especially likely for application in developing countries. Improved adaptation strategies are needed, which necessitate more climate data inputs as a basis.

Munang *et al.* (2013) reported that in most developing countries, particularly in Africa, understanding the dynamics of local climate is urgent, so as to make predictions to respond to climate variability and change and adapt as appropriate. The economies of most developing countries are heavily reliant on climate-sensitive sectors; such as water, agriculture, fisheries, energy and tourism. CC therefore poses a severe challenge for social-economic development in developing countries. They further report that African countries are among those least likely to have the resources required to support large-scale data rescue initiatives. Figure 1.8 shows adapted features of a hut in Southern Africa, where the foundation is shown to be raised after building construction and there is an attempt to minimize water penetration from the roof.

Cost-effective, small-scale data rescue projects in developing countries at local and district levels could meet basic data requirements and preserve the precious historical data to improve the ability for local climate prediction and weather forecasting. With limited funding and efforts, small-scale climate data rescue projects complement the above-mentioned large-scale efforts and have significant social and environmental impacts on the livelihoods of local communities. Olorunfemi (2009) is one of the researchers who suggested the need for a study that will develop backgrounds for methodology to assess the status of public awareness among the populations in Nigeria on CC, coping mechanisms and adaptation strategies. Using empirical data and analysis, the study addressed these issues and justified the need to integrate people's knowledge and understanding of CC and potential response measures into existing development structures, particularly those which promote participation of end users in Nigeria.

1.8 Purpose statement

To overcome these setbacks, research carried out on the local level, such as this research, is imperative (Figure 1.9). Smit and Wandel (2005) determined that one common drive of adaptation studies in the CC field is to approximate the degree to which modelled impacts of CC scenarios could be moderated or offset by adapting to the impacts (Parry, 2002; Mendelsohn *et al.* 2000; Fankhauser, 1998 in Smit and Wandel, 2005). These analyses address Article 2 of the United Nations Framework Convention on CC (UNFCCC), which requires countries to mitigate greenhouse emissions in order to avoid "*dangerous*" anthropogenic changes in climate. Adaptations are considered to assess the degree to which they can moderate or reduce the negative impacts of CC, or realize the positive effects, to avoid the danger.

Ikejiofor (1999) suggested that the most compelling reason for reviewing documented reported of traditional domestic architecture is because buildings that derive from rural traditions remain extraordinarily ancient as dwellings, because they are directly related to the economy and way of life of their users. Surprisingly, very few studies have reported on why some communities adapt and others do not. This research used Multi-Criteria Analysis to determine the economic impact of sustainably adapting to cc.

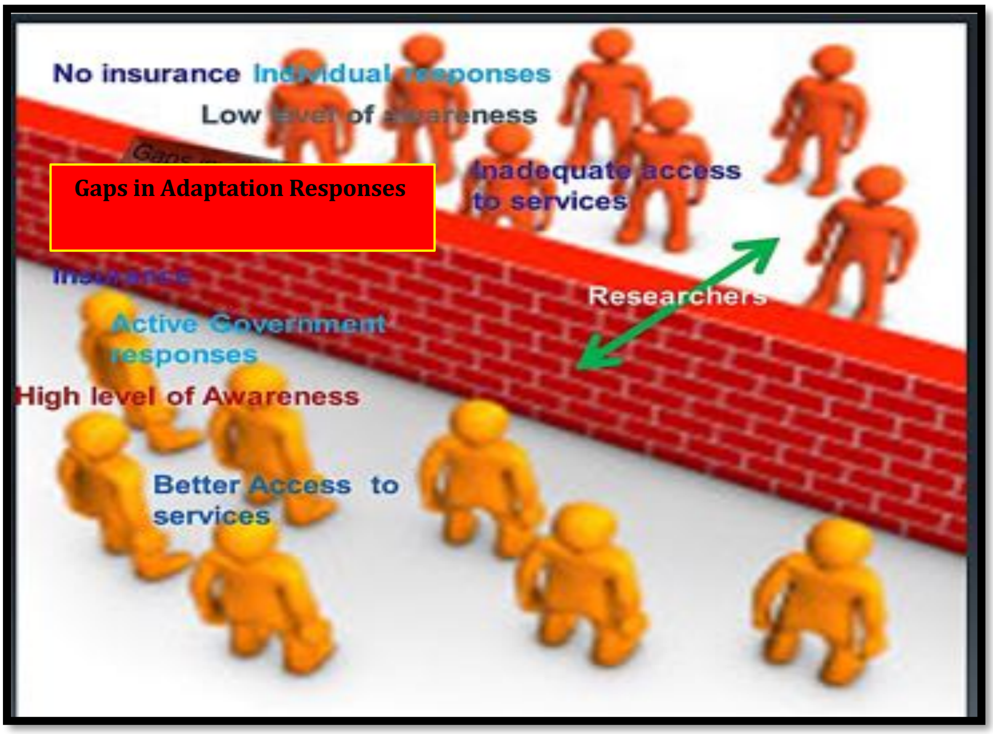


Figure 1.9. Bridging the gap for adaptation, (author's description, 2016).

1.8.1 *Aims*

The study will evaluate the impact of CC on the Benue environment by recognizing key CC indicators in the region, with a primary aim to investigate how people are adapting and provide data to aid informed approaches to adaptation. It will further investigate possible factors that inhibit adaptation and develop a model for adaptation for *Tiv* (a local tribe in Benue State) traditional buildings for the impacts of CC.

1. To critically study the key indicators of CC and its' impacts on the built environment of Benue and collate and appraise appropriate climatic data for the region.

2. Identify various types/forms of Benue traditional architecture and evaluate the influence of *Tiv* architectural ideology on the environment.

3. A cost model of an adapted traditional building will be developed to analyse the economic, social and environmental benefits. It will be argued that its benefits will outweigh costs.

4. To critically study the influence of culture on *Tiv* architecture and building concepts using the Economic, Environmental and Social aspects (Multi-criteria Method) to examine the influence of culture on these parameters.

5. The performance of a model will be assessed against indicators of CC, such as temperature, rainfall, floods and durability and compare the performance of the case study against a control project and analyse collected data using appropriate statistical software.

6. Appropriate policy recommendations to government based on the empirical results.

The research seeks to answer the following questions:

1. How do affected persons understand and respond to CC impacts? In what ways, if at all, do they prepare for the next impacts?

2. What sources of data on CC adaptation does the community use and perceive to be most dependable?

3. Who do people feel is responsible for tackling CC?

4. To what extent is CC perceived as a personal risk, a priority environmental distress, or an issue of personal importance?

5. What constitutes the public behavioural response to CC?

6. What are the motivations and barriers for adapting to CC impacts?

The value of this research will be in contributing a practical approach for communicators and policy-makers involved in engaging communities in the issue of CC adaptation and developing practical adaptation strategies with the use of available data. This requires an understanding of the multiple, social 'realities' and responses to CC.

1.9 Brief outline of methodology chapter

The methodology Chapter will discuss an overview of the experiment/design population/sample, location, limitations, sampling technique, procedures, materials, variables and statistical treatment. It shall also justify the rationale for choosing a mixed method approach.

1.10 Structure of thesis

The thesis is divided into seven Chapters. The Introduction Chapter gives a general view of CC scenarios in the tropics and then specifically to the case study area, the need for this research and the aim and objectives that satisfy the aim. Brief definitions of keywords will be given. Secondly, the literature chapter reviews past work on the subject of CC adaptation and how people perceive it. It will also identify gaps in the field and point out where this research fills some of the gaps. Thirdly, the Chapter will show a detailed approach to the methods used for data collection and the reasons for the approach. Steps taken to meet the aim of the research will also be discussed. Chapter four analyses the impact collected data has on the community's ability to adapt. Chapter five discusses key findings and the community's perception of adaptation to CC impacts, possible coping mechanisms, inhibition to adaptation and possible ways forward. In chapter six recommendations and conclusions will give possible ways to combat CC impacts in the community and how authorities may reduce these impacts.

1.11 Summary of Chapter one

Chapter one has described the context in which this research progresses. It has defined how adaptation to CC emerged and has now become a major environmental, social and political debate. A description of the action at the national and international government level outlined to tackle CC impacts is given and why their strategy has not achieved its goal for reducing the impact of CC in the community is put forward. The Chapter also provides insights into some of the challenges facing policy-makers in engaging with the public over CC impacts and indicates why there is a need for social science to provide insights into the public's awareness and response to the issue. Finally, the theoretical basis and aims of this thesis are described.

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

Climate change has been identified as a major threat to human and environmental well-being that demands a global response. However, researchers and policy-makers face multiple difficulties in terms of raising awareness of CC and promoting appropriate behaviour in communities. This Chapter reviews the research that has been conducted to date on public perceptions of and responses to CC, where appropriate drawing on illustrative understandings from concepts of risk awareness, sociology of knowledge and environmental behaviour. This presents an interdisciplinary perspective on how individuals perceive, understand and respond to CC. Previous research on actions on adaptation and responses to flooding, temperature variation and other responses are also discussed. The focus of this review is on the Nigerian perspective, although research in other countries is discussed where relevant.

2.2 Theoretical framework

2.2.1 *Adaptation approach to addressing impacts of climate change*

Much recent work by Ziervogel *et al.* (2016) indicated that there is rising concern in cities, towns and local communities on CC adaptation and how best to minimize the multiple impacts of CC. They class different stages as follows:

1. At the local government level, planning adaptation is an important step in establishing the framework through which to implement adaptation.

2. The alignment of climate adaptation with existing government priorities and policy, to meet multiple objectives and increase the efficiency of human and financial resources.

3. Understanding the opportunities for developing adaptation plans that align with development priorities is particularly important in the global South, yet this has not been explored sufficiently in the literature.

4. Developing adaptation plans and policies requires a robust but realistic understanding of CC science, vulnerability to climate impacts and the broader socio-economic and governance context in which adaptation might occur.

5. Local government decision-makers are likely to be familiar with the governance and socio-economic context, but often lack understanding of the climate science and vulnerability, which requires engagement with researchers and users.

6. Understanding how policy interfaces with these different knowledge in a practical sense is thus critical in developing local adaptation plans.

In contrast to the literature on climate adaptation and mitigation policy, Singh *et al.* (2017) found that the most research on climate adaptation has focused on sociological concepts to assess a community's vulnerability or capacity to adapt to the effects of CC. They agreed with multiple authors (e.g. Brooks *et al.* 2009; Grothmann and Patt, 2005; Kelly and Adger, 2000; Pelling *et al.,* 2008; Smit and Wandel, 2005).

Studies imply that preparing proactively for expected local CC impacts can increase a community's capacity to adapt, as it provides added preparation time to raise money and implement tasks to increase the adaptive capacity of communities. Singh *et al.* (2007) concluded that such sociologically-based theories are insufficient because part of a community's ability to adapt to CC will also depend on the level to which that community embraces the government organizations focused on preparing for and adapting to CC impacts. Therefore, a more in-depth understanding of the underlying factors driving support for adaptation may help policy-makers understand if or when an adaptation policy may gain traction at national or subnational levels.

Ziervogel *et al.* (2016), in agreement with Singh *et al.* (2017), suggested that very little has been written regarding the challenges and opportunities of integrating climate science and local knowledge into adaptation policy and planning. The literature on the challenges has concentrated principally on CC and awareness but has left a gap between researchers and users. Van den Hove (2007) defined science-policy interfaces as "*social processes which encompass relations between scientists and other actors in the policy process and which allow for exchanges, co-evolution and joint construction of knowledge with the aim of enriching decision-making".*

Several authors have described that a lack of empirical evidence makes it difficult to measure and envisage the impacts of CC relative to other extinction drivers such as loss of habitats, intrusive species, disease and over-exploitation of natural Resources. Sodhi *et al.* (2011) drew particular attention to the insufficient data in temporal evidence, confirmed with rapid changes in tropical landscapes as human populations and economies grow. Wright (2005) argued that "*tropical forests also have an unequal role in global carbon and energy cycles and support 50% of described species and an even larger number of species not described. An understanding of anthropogenic change in tropical forests is thus crucial to understanding global CC and the conservation of natural habitats*".

Wright (2005) argued that throughout the 21st Century, CC impacts are projected to slow down economic growth, make poverty reduction more difficult, raise further threats to food security and extend existing and create new poverty traps, particularly in rural areas, thereby further developing concentration of hunger. In both developed and developing countries, CC impacts are expected to aggravate poverty in most rural areas of developing countries and create new poverty pockets in countries with increasing inequality.

2.3 Evidence and indicators of climate change

Corlett (2012) defined indicators as quantitative or qualitative measures that can be used to describe existing situations and measure changes or trends over time. He refers to performance indicators as criteria for success. In the context of the logical framework approach, at least one indicator should be defined as a performance standard to be reached in order to achieve an objective. Indicators should include both outputs and outcomes (impacts), with explicit statements of how the indicator demonstrates that the project goal has been met and what the functional relationship is between a change in the indicator and the outcome of a project.

Kenabatho *et al.* (2012) stated that CC is real and evidence of its impacts can no longer be ignored. They went further to assert that one of the most important and measurable CC impacts will be increased temperatures as a result of global warming. "*This warming will inevitably lead to significant variability in atmospheric processes such as rainfall formation and occurrence, evaporation rates as well as atmospheric humidity*" (Kenabatho *et al.,* 2012). The paper concluded that some of these changes are already happening, evidenced by rising sea level, melting ice sheets and extreme temperatures (Figure 2.1).

The occurrence of intense precipitation events is increasing over many northern mid-latitude regions. Instances of extreme summer heat, often combined with high humidity, have increased in most world regions. El Niño/Southern Oscillation (ENSO) episodes over the last two decades have been both unprecedentedly large (e.g., 1997/98) and prolonged (e.g., 1991/94; Trenberth and Hoar, 1997); and severe hurricanes (e.g., Hurricane Mitch) and extensive riverine (e.g., Mozambique) and coastal flooding (e.g., Orissa) have led to many tens of thousands of premature deaths (Adger, 2006).

Figure 2.1. Evidence of CC melting ice sheets, rising sea level and drought. (source: National Aeronautics and Space Administration, 2014).

Yau and Hasbi (2013) were some of the first researchers to point out the contrasting effects CC is producing on the built environment in various regions of the world. They argued that in Asia, the building sector appears to be more vulnerable to the impact of CC occasioned by flooding, while the building sectors in Australia, Kenya and Brazil on the other hand, are grappling with the impacts of drought. Gutiérrez (2013) suggested that some regions of Brazil, particularly the semi-arid north-east witnessed (from 2010–2013) the worst incidence of drought since records began. Ren *et al.* (2011) expressed the opinion that reduction of vulnerability, particularly in the building sector, can be achieved by improvements in adaptive capacity. That is, the ability to respond to climate variability and change, to reduce or moderate the likelihood and the magnitude of harmful outcomes, to cope with the consequences, or to take advantage of opportunities.

Salinger *et al.* (2005) argued that South-East Asia is particularly vulnerable to CC impacts as a result of significant reliance on agriculture and high population density. However, Perez (2014) suggested that the longer it take, the more vulnerable we will become, the more you implement adaptation measures and the more people in these regions will become aware of the urgency to adapt.

Some of the evidence of CC that will be discussed in this research is:

- Temperature.
- Flooding.
- Rainfall.
- Vegetation.

2.3.1 *Temperature*

Singh *et al.* (2014), pointed out that the effects of extreme climate events, such as droughts are well covered by the literature. Several CC modelling studies also indicate that the tropical regions of Asia and Africa could experience a significant change in the frequency of occurrence and the intensity of droughts over a period of two decades and found significant variation along North-South gradient (36-24^{0}C <600-6000 mm/yr). Citing Nicholson (2009), they concluded that the region is within the Inter Tropical Convergence Zone (ITCZ); therefore, climate in West Africa is governed by the tropical rain belt and the West African monsoon. The tropical rain belt lies 10^{o} south of the ITCZ; during boreal summer (June, August) insolation results in a north-ward shift in the ITCZ and the development of an area of low pressure over North Africa (Gosling and Miller, 2014) According to Tachikawa *et al.* (2014) a climate-model based study for evidence of CC in the Pacific region appears to indicate a higher tropical sea surface temperature rise relative to the subtropical regions in response to increased greenhouse gas concentrations. From the study, this situation is particularly apparent along the equator. Figure 2.2 illustrates temperature variation in Mali and The Gambia (1880-2010) (Widlansky *et al.,* 2012 in Tachikawa *et al.,* 2014).

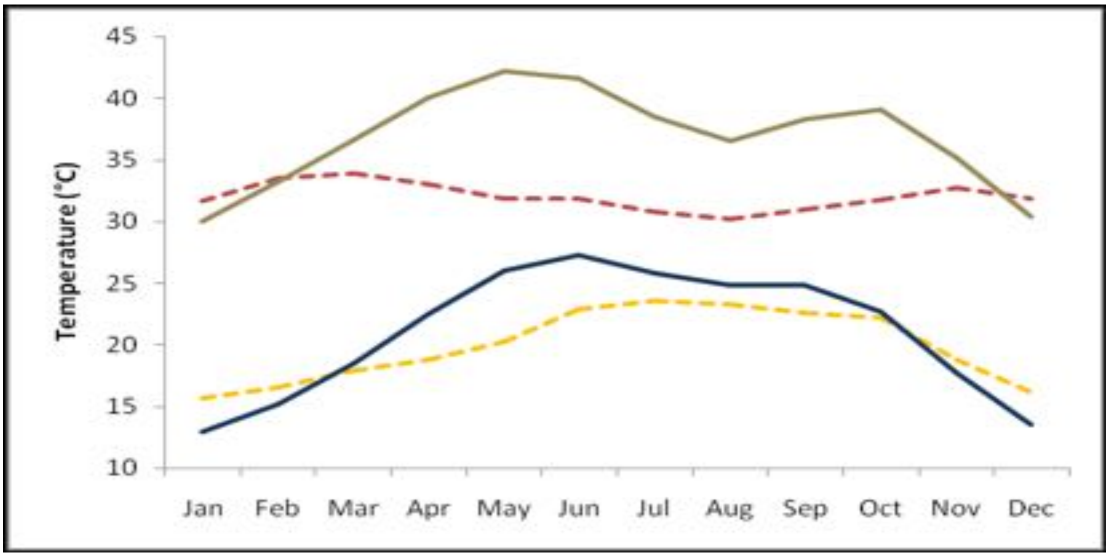


Figure 2.2. Mean temperatures of Tombouctou (Mali, solid line) and Banjul (The Gambia, dotted line) (source: Climate Risk Assessment and World Meteorological, 2014).

Wilson *et al.* (2019) reported that in tropical Africa and South-East Asia, record cooling are evident with as much as 40-50^{o}C cooling at the last glacial maximum.

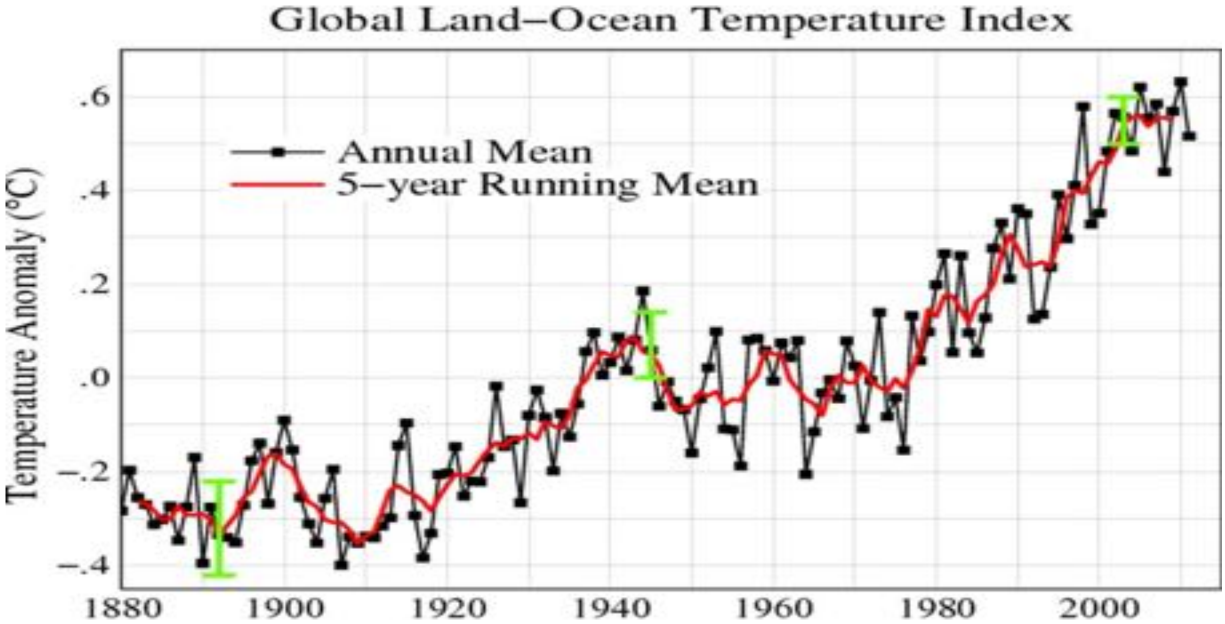


Figure 2.3. Global temperature anomaly 1880-2010, (source, NASA, 2011).

Fig 2.3 shows Global temperatures (1880–2000). Although there is evidence of gradual temperature increases dating back to the industrial era, (NASA, 2011), recent studies indicate more rapid increases from the mid-1980s.

Relationship between a relatively warm southern hemisphere and cool northern hemisphere with dry conditions is dynamic on numerous time-scales, from years to millennia and is stated most dramatically in the multi-millennial changes linked with cold cycles (Brooks, 2009). It was argued that through the last glacial maximum, when the northern hemisphere was significantly colder than the southern hemisphere, due to the growth of huge ice sheets, the Sahara Desert was much larger and more arid than today (Talbot, 1983 in Brooks, 2009). After the end of Ice Age, intense summer heating of the northern hemisphere has intensified the African monsoon, transforming the Sahara into a landscape of lakes, savannah and open woodland (Szabo *et al.* 1995 in Brooks, 2009).

Over Savanna, in the first period (1910–1939) rainfall ranges were between 1100-1400 mm with 42% of the total annual rainfall >1250 mm. The second period's annual rainfall received increased and ranged between 1000-1400 mm (1940–1969), with ~38% at 2000 mm. A reduction was observed during the third climate period (1970–1999) where the minimum to maximum received rainfalls were between 950-1360 mm with 30% of the total distribution at ~1150 mm. Over the Sahel, the first period (1910–1939) rainfall range was between 480-1000 mm with ~23% of the total annual rainfall 760 mm. The second period's annual rainfall received reduced and ranged between 580-1000 mm with 28% at 740 mm. Further reduction was observed during the third climate period when the minimum to maximum received rainfall was between 500-920 mm with 35% of the total distribution at 700 mm. This indicates a northward reduction in annual rainfall, as supported by previous studies (Adefolalu, 1986; Bello, 1998; Oguntunde *et al.* 2011).

2.3.2 *Flooding*

ICSU (2007) reported that floods are among the most devastating natural hazards in Africa, whereas flash floods are among the greatest hazards arising from tropical cyclones and severe storms. Floods and flash floods cause loss of life, damage to property and promote the spread of diseases such as malaria, dengue fever and cholera. From 1900-2006, floods in Africa killed nearly 20,000 people and affected nearly 40 million more and caused damage estimated at ~four billion dollars. According to the IPCC (2007), continual warming of the Earth could lead to the melting of Alpine ice and thermal expansion of seawater, which will eventually result in significant rises in sea-level.

Flooding affects more people globally than any other natural hazard and to 20% of the world population lives in river basins and are likely to experience increased flood events by 2080 (Metcalfe and Nash, 2012). They stress that these impacts are likely to be felt more severely in rural and undeveloped tropical regions. Climate-driven disasters have emerged as the most glaring challenge of the 21st Century, with floods being the most disastrous, frequent and wide spread consequence (Dhar and Nandargi, (2003) in Metcalfe and Nash, 2012). Cornway (2009) emphasized that floods will become more common in Africa, in part because some regions will experience higher rainfalls, but even in drier areas, there is likely to be a higher occurrence of more extreme rain storms, which may create flooding.

Munji *et al.* (2013) reported that developing countries bear the primary burden of climate-related extreme events. In particular, South-East Asia and Sub-Saharan Africa and small island States are the most vulnerable (IPCC, 2007). The study further indicated that 94% of climate-driven natural hazards between 1990-1998 occurred in developing countries (IUCN, 2007). In recent decades, extreme floods have affected many areas around the world, especially in developing countries, with resultant economic damage and human desolation particularly in rural areas (Mirza, 2003). With projected sea-level rises, due to climate change, flood occurrence is expected to quadruple by 2080 (IPCC, 2007).

Wilson *et al.* (2019) argued that 100,000 years of consistency of ice ages were disrupted by shorter and sharper episodes of climate change, believed to have been induced by sudden collapse of icebergs, inevitably causing floods. Sodhi *et al.* (2011) argued that generally CC will mostly affect the tropics. Figure 2.4 shows a survey result indicating that all the groups have witnessed and been victims of coastal flooding, with the blue group (areas with low mangrove forest cover) the most exposed to coastal flooding. Figures 2.5 and 2.6 show flood prone areas in Nigeria and Benue State is one of them.

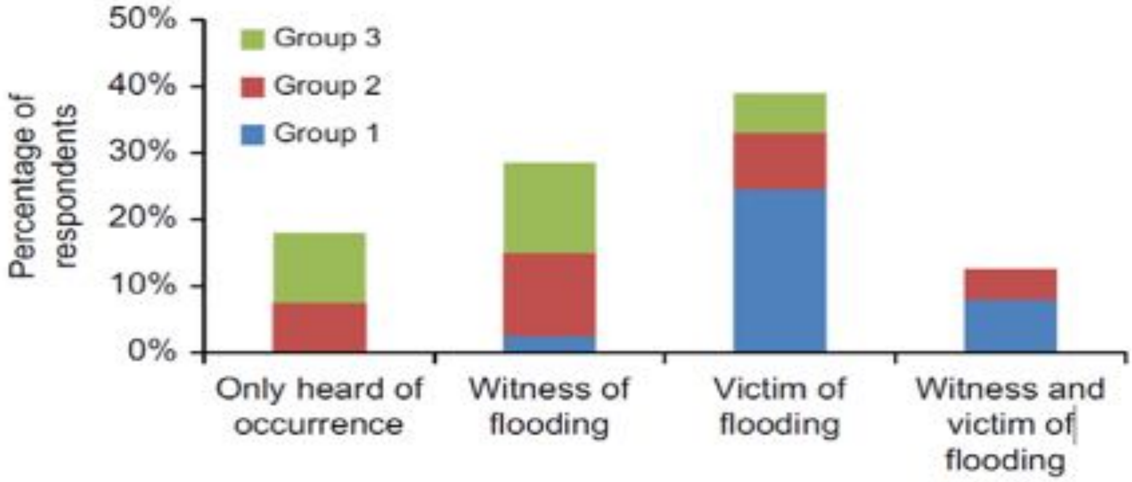


Figure 2.4. Perceptions on experiences with flooding, (source: Munji *et al.,* 2013).

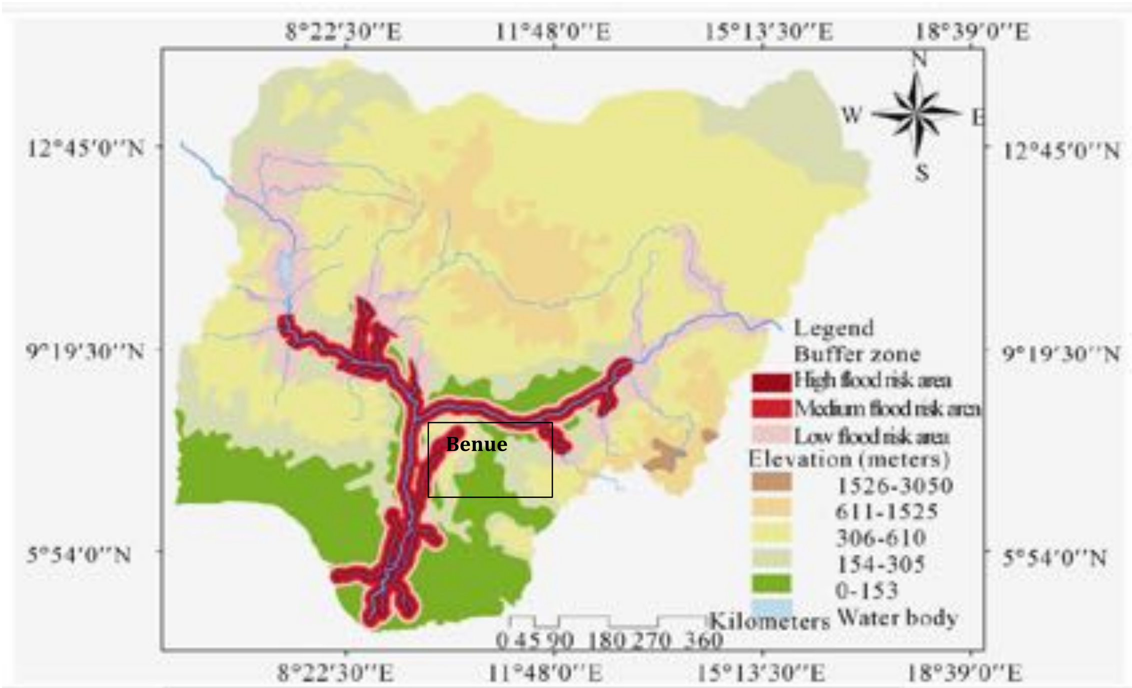


Figure 2.5. Flood risk in the Benue Niger Basin, by magnitude of high, medium and low risk areas (source: Clemet, 2012).

2.3.3 *Rainfall*

The International Livestock Research Institute (2014) suggested that a small number of short intense storms are responsible for most of rainfall in the tropics, although this might also be true for other regions outside the tropics. Consequently, 10-15% of rainy days account for 50% of rainfall, 25-30% of rainy day's account for 75% of the rainfall and 50% of days with the smallest rain amounts account for only 10% of the total. In semi-arid regions, such as Northern Kenya, the pattern is even more obvious. Almost half the rainfall events over a two-year period contributed <2% of the total rainfall and they had rainfall intensity <5 mm. On the other hand, 6% of the storms fell with intensities >25 mm and these storms contributed >70% of total rainfall (Edwards *et al.* 1979, in The International Livestock Research Institute, 2014).

According to Kenabatho *et al.* (2012) it is projected that more extreme events such as floods and droughts will occur, the onset and duration of rainfall seasons will change and rainfall variability will increase leading to a more uncertain future (Buytaert *et al.* 2010; Chiew *et al.*2010 in Kenabatho *et al.* 2012). Arid and semi-arid areas are likely to be severely affected because of limited water resources and low adaptive capacity to cope with the effects of CC. Rainfall and temperature changes are major determinants of recently observed trends in agricultural production in Sub-Saharan Africa (Roudier *et al.,* 2011) Lodoun *et al.* (2013) showed rainfall fluctuation in Burkina Faso to confirm the change in rainfall trends (Figure 2.6).

Nigeria's rainy season is due to last longer than standard; they predicted that floods and disease will damage the nation's cocoa crop if adaptation measures are not taken (NIMET, 2015). Nigeria is the world's fourth-biggest cocoa producer. It is forecasted that the late December season will last about a month longer than 2014.

2.3.4 *Vegetation*

West African vegetation is predominantly grasslands and forests which act as a sink in the global carbon cycle (Wang and Eltahir, 2000, in Gosling *et al.* 2013). The distribution and composition of tropical West African vegetation is strongly linked to the prevailing climate (Holdridge *et al.* 1971, in Gosling, 2013). However, over the coming decades, regional climate models suggest that temperatures will increase and precipitation regimes, such as the West African Monsoon, will alter (Christensen *et al.* 2007 in Gosling *et al.* 2013) (Figure 2.6). The response of vegetation to the projected CC remains uncertain. One way in which the understanding of the relationship between vegetation and climate can be improved is to examine fossil records, which span long periods of global CC of a comparable magnitude.

Challinor *et al.* (2007) used regional climate modelling simulations for the present climate and one future climate situation, together with a process-based crop model, to quantify the impacts of temperature changes on crops. They discovered that high temperature stress was not the main determinant of simulated yields in the current climate, but affected the mean and variability of yield under CC. They quoted Roberts and Summerfield (1987) as saying "*sustained temperature increases over the season will change the duration (from sowing to maturity) of the crop*". Njokuocha *et al.* (2014) observed that although Nsukka is mostly a lowland rainforest area, (Figure 2.7) evidence indicates that the area has recently become drier with a distinct vegetation change showing a transition from southern Guinea savannah vegetation to derived savannah mosaic vegetation.

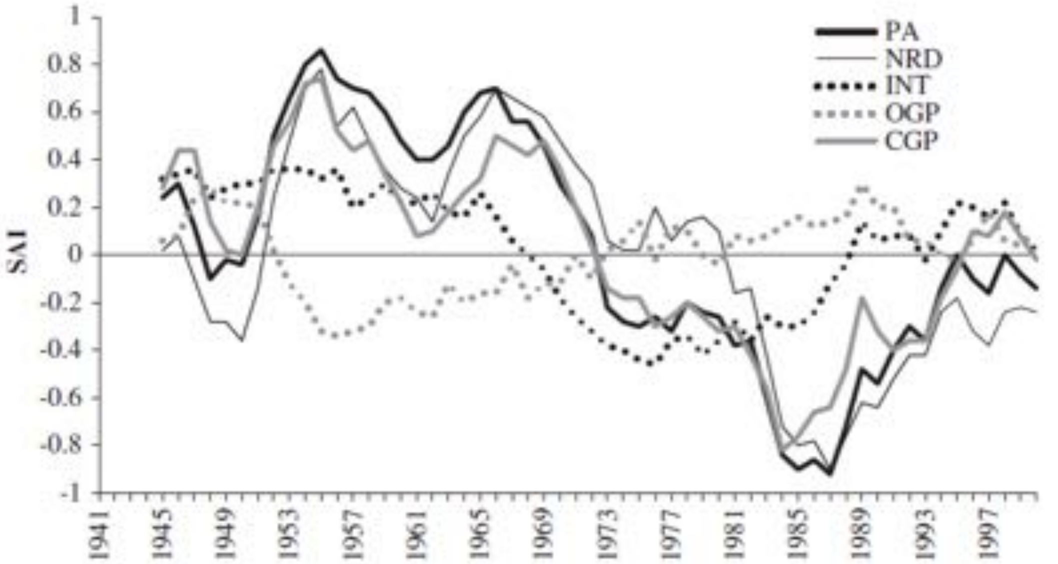


Figure 2.6. Fluctuations of the rainfall descriptors in Burkina Faso between 1941-2000, (source Lodoun *et al.,* 2013).

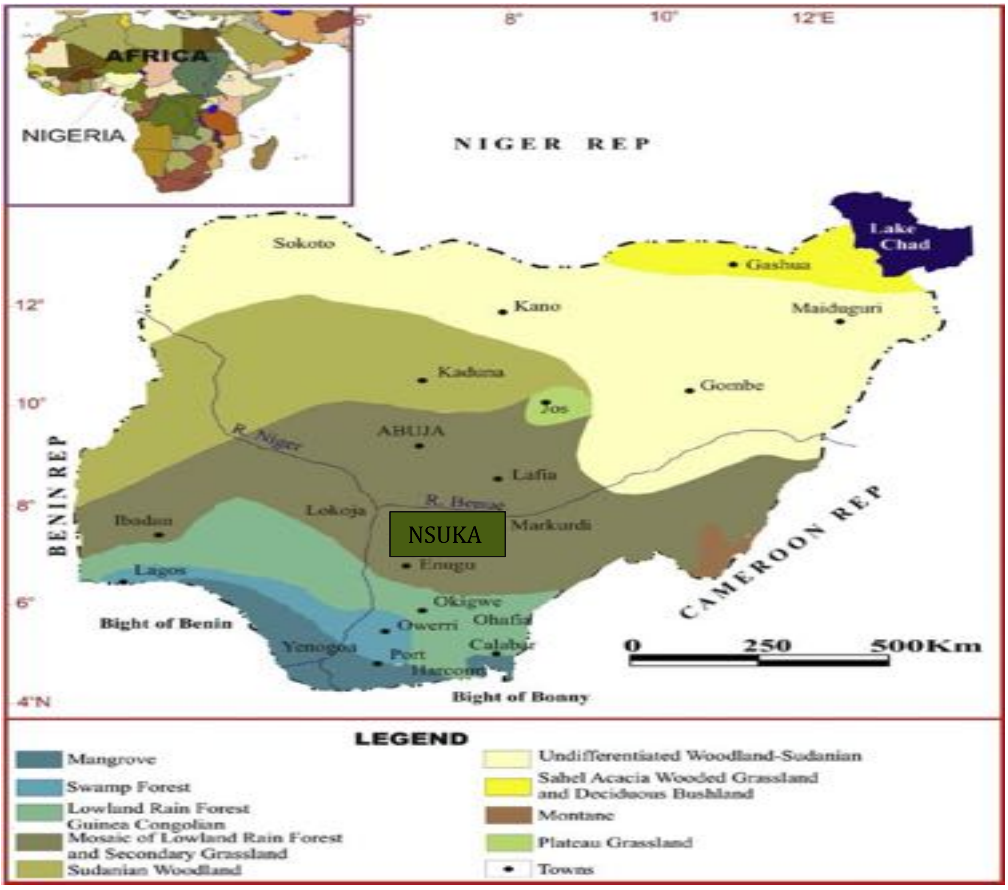


Figure 2.7. Vegetation zones of Nigeria, (source: Njokuocha *et al.,* 2014).

2.4 Forms and functions of traditional architecture

Osasona (2001) argued that the knowledge of constructive and logical traditional architecture is important to enable understanding any of the functions and forms of the design in traditional settings. One of the reasons for the difference in forms is the diversity of ethnic groups with different cultural practises. There is a focused on the traditional built form in Nigeria, using the traditional hut of the *Tivs,* usually referred to as "Ate". An overview of materials, forms and techniques generating the traditional forms of architecture is presented.

'*Vernacular architecture'* is a brand of architecture resulting from the cultural being conditioned by external forces. Such influences of a socio-political and socio-economic nature constitute diffusions from a '*more advanced'* to a '*less developed'* culture (Osasona 2007).

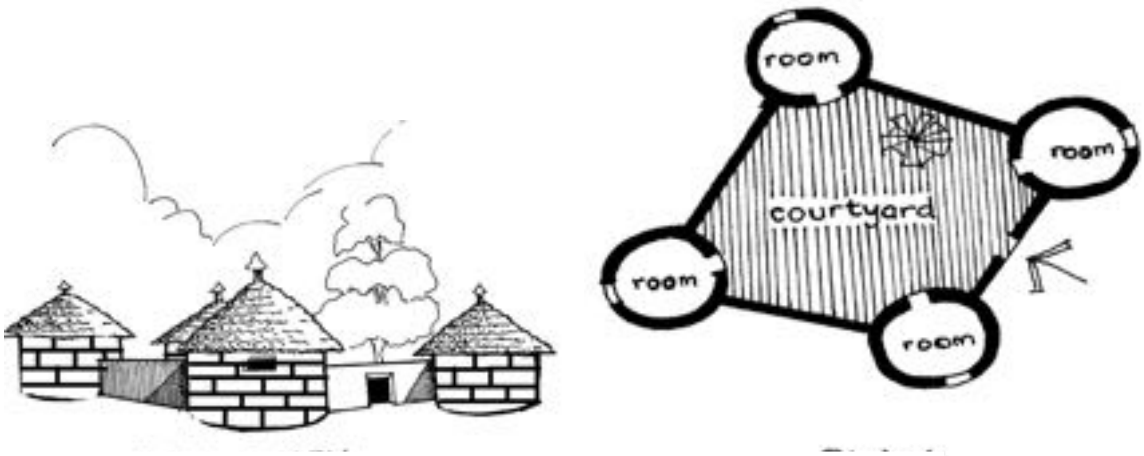
Architectural forms are a part of what define a tradition (Amole, 2000, p. 17, in Osasona 2001). A major point of departure between the two brands of architecture is that, whereas the traditional was essentially spontaneous, with designs and construction techniques carried over from one generation to the next and for the actual building process, a community enterprise was lacking specialists. However, vernacular form is greater individuality, more conscious decision-making and specialization resulting in division of labour (Osasona, 2001, p. 16-17).

Other prominent characteristics of traditional architecture include the fact has evolved from a process of selective borrowing: the traditional becomes exposed to other stylistic influences and over time, certain features and characteristics become subtly imbibed and 'communalized', while others are excluded. Because the process is gradual, communally generated and participatory, the architectural brand which evolves is spontaneously identified with wide suitability. According to Rapoport (1969, p 2), it is "*more closely related to the culture of the majority and life as it is really lived, than is the grand design tradition*". Additionally, it "*shows an instinctive command of particular materials".*

2.4.1 *Dialectics and philosophical basis of African traditional architecture*

Ikejiofor (1999) reported that the rising debate on African philosophy is historically linked with two transmitted occurrences, Western discourse on Africa and the African response to it. The negotiation has taken many forms and includes various philosophies portraying the individual's role and impact in the shaping and control of one's identity and destiny.

Bandyopadhyay and Green (2013) reported that on African decolonization in the 1950s and 1960s, social scientists were apprehensive about the need for what was then called ‘‘national integration" in societies with multiple ethnic, religious and racial cleavages, although no one has examined the effects of nation building on national integration in post-colonial Africa. Ikejiofor (1999) analysed studies of residential habits among two cultural groups in the Middle belt zone. He found that, among the *Tiv* of Benue State, the spatial organisation of living units in the compound reflects the closeness within family relations. The oval plan of buildings gives each member of the compound equal, visual and physical access to the central courtyard area, highlighting this emphasis. The enclosed arrangement of a *Tiv* traditional compound reflects the closeness of relatives (Figure 2.8).



Exterior **Plan**

Figure 2.8. Typical *Tiv* compound, (adapted from Ikejiofor, 1999).

Figure 2.9. Typical *Tiv* compound Benue State, (source: Jev, 2015).

2.5 Epochs in African traditional architecture

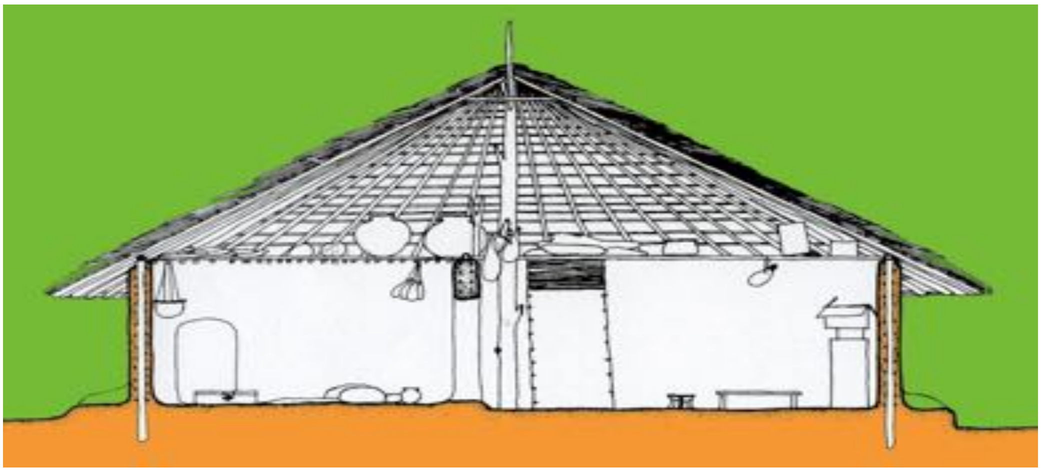
Ikejiofor (1999) reported that over time, the architecture of the *Tiv* populaces is developing, as well as traditional residential architecture in Nigeria as a whole. He further described the traditional houses of peasants and their way of living as far easier to see the relationship between environment and habitat in these dwellings than in the case of the big city architecture of Western countries.

The architectural forms and expressions of the buildings are not dictated by aesthetic concern, but by often unconscious understanding of the landscape and cautious use of locally available materials. He further explained why the conscious design process achieves good forms using the theory of Architectural Darwinism. This was defined by Alexander *et al.* (1977) as a collection of design constraints extracted from traditional architecture aimed at improving human adaptive needs, while leaving the form and visual aspect unspecified. The possibilities of a Darwinian process of design are tied to the system of options within which it operates and the richer the structure is, the broader the field.

Uduku (1996) researched architectural designs in east Nigerian cities and reported that it is clear that the most distinguishable trends in the development of the urban housing fabric in Eastern towns are in two directions. First; the preservation of traditional Western urban design and planning models in the formal sector. The second direction is towards the use of more native design materials and local planning measures being adopted by members of the informal sector.

Ejiga *et al.* (2012) argued that although African architecture does not have a documented scientific approach to its design and construction, it does not mean that it fails to satisfy these conditions. For a building system proven to satisfy thermal comfort, aesthetics and sustainability and being a major part of the daily life of its occupants cannot be anything short of good architectural form. Okoye (2012) agreed that these architectural forms serve the purpose of shelter, protection and are environmentally-friendly.

Figure 2.10. Cross section of a Traditional hut, (source: Ikejiofor, 1999).



Olutuah (2009) asserted that the roles and performances of housing experts in identifying the housing problems of the nation, are of serious concern. He referred to Gilbert and Guggler (1994) who argued that there is a misunderstanding and that there are wrong priorities in the perception of the actual needs of the poor by professionals. Examples include, many luxury items (such as flush toilets and bath tubs), large space criteria and designs, which are clearly in disagreement with the real needs of poor families in developing countries, as they lead to high household cost. In circumstances of poverty, an important criterion in housing quality is the match between the housing and the needs of particularly poor families. Gilbert and Guggler (1994, in Olutuah, 2009) further asserted that it is frivolous for poor people to live in housing of high architectural standards, which does not equal their needs and incomes. The inability of architects to put housing problems into proper perspective is partly as a result of inadequate architectural education, especially on rural housing matters and thus detected and perceived deficiencies can be traced to the prospectus of study they went through. As asserted by Turner "*problems cannot be properly stated unless the underlying issues are understood*" (Turner, 1976 in Olutuah, 2009). African traditional architecture is essentially sustainable and has evolved culturally to suit the people. Usually, earth, timber, straw, stone/rock and thatch were constructed together with simple of tools and methods to build simple and habitable dwellings.

2.6 Nigeria in context: ethnography, history and *Tiv* architectural forms

Raffelt *et al.* (2013) argued that the rise of the modern organisation following the Industrial Revolution of the 19th Century was complemented by architectural styles that replicated the spirit of the times. Initially, communal architecture followed the principle "*form follows function*" that was first formulated by American architect Louis Sullivan in 1896. Sullivan's principle became closely associated with the functionalist. The *Tivs* are positioned within the three broad ecological zones of Nigeria (Figure 2.11).

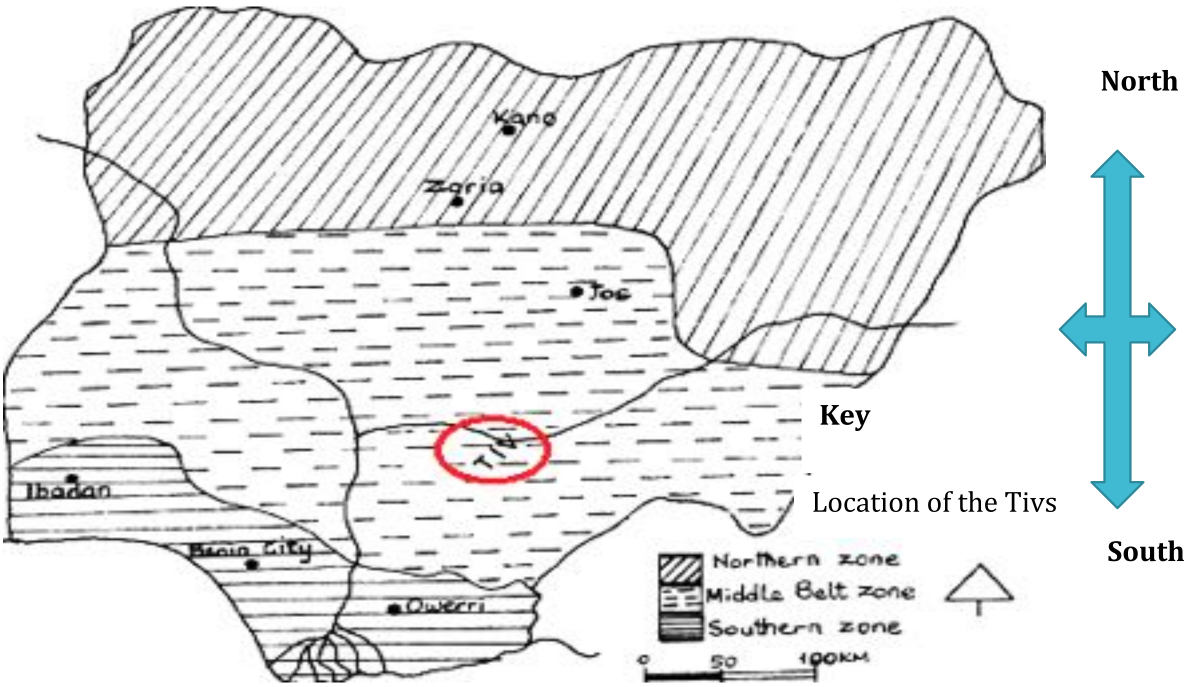


Figure 2.11. Map of Nigeria showing the three broad ecological zones with *Tiv* in the Middle belt, (source: Ikejiofor, 1999).

Ejiga *et al.* (2012) described the indigenous architectural practise of rural Nigeria as being shaped by philosophies of sustainability, though done in scientific ignorance; developed from natural materials and recurring possibilities of their regeneration, they impacted on the thoughtful use of Earth's resources in construction. In reality, the act of choosing a site, utilization and re-use of materials and sites in that respect have all been formed by the culture of simplicity and economy, respecting nature and understanding that the Earth must be gently cared for because it is both delicate and consumable (Dayaratne, 2000, in Ejiga *et al.* 2012).

Predictably, earth/mud has been one of its most important building materials combined with timber (mostly from palm trunks) and palm, coconut, grass thatch and straw bales as roofing; all materials abundantly available in the settlements. Stones were used when available. Africa's traditional architecture made its use of available resources did not adversely affect the ecological balance of agricultural societies.

2.7 Determinant factors in *Tiv* architectural forms

Ejiga *et al.* (2012) suggested that the architecture of Africa has been seen and labelled internationally and by its people, as primitive. This ‘primitive’ classification comes partially from the building materials and their relatively low technological uses when compared to present day Western (architectural) construction techniques which result in (e.g. skyscrapers. The definition of architecture as the art and science of building has, over the years, seen many reforms to include usability, acceptability and comfort. The main occupation of the *Tivs* is farming with most incorporating storerooms as part of the building. The roof structure in Figure 2.12 shows some of the natural materials used in the construction of the hut.

Oppenheim (1992) stated that African architectural forms offer a structure of orientation within which social, economic and physical events are grasped together, integrated in the mind and, in planning the evolution and development of a region's life. Ogundele (2007) argued that storerooms cannot be reduced to a mere economic demonstration without omitting some fundamental perceptions of people’s cultural life. For instance, storerooms are typically constructed on a communal basis. Designers and builders are not paid in cash, although food and drinks are regularly given to them. Granaries are the most sophisticated constructions in *Tiv* land (Ogundele, 2004, p. 11 in Ogundele, 2007).

The designing and building of granaries are relatively more laborious and more energy consuming than other forms of constructions in the study area. This exercise may last between two and four weeks to accomplish, depending on the size of the granary and the level of skill of the builders and their number. Ogundele (2007) found that a storeroom is called “*Ate”* in the *Tiv* language. Although they live in the same zone with the Ungwai, *Tiv* storerooms as well as other architectural forms differ in some fundamental ways. This evidence of cultural diversity is inseparable from the factor of social history. Such a development underscores the dynamics of group identities among human societies around the world. The storeroom, which is a core part of a *Tiv* compound, is even more difficult to build than building a living house or a central/ communal hut.

Figure 2.12. Preparing roofing frame for *Tiv* hut / finished (breathable) interior of a typical African roof, (source: Tyman, 2014).

Ikejiofor (1999) believed that the main determinant factors in *Tiv* architecture form are the economy and way of life of the people. Olutuah (2009) described housing as a reflection of the cultural, social and economic values of a society. It is, in particular, a cultural spectacle which finds appearance in people’s ability to meet their needs of shelter in the context of their communities.

The role of culture in housing is predominant, notwithstanding the moderating effect of economics, climate and technology. Housing as a subset of traditional architecture evolves from the culture of a community in accordance with the lifestyle of its people, the construction materials available and the technical possibilities open to them.

Research has confirmed the profound inadequacy in the housing circumstances of Nigerians, in particular the low-income population (Olotuah and Fasakin, 2003; Olotuah and Aiyetan, 2006 in Olutuah, 2009). Ejiga *et al.* (2012) argued that although globalization has demoted them as being 'primitive', present understandings of sustainability have given them a new status as potential technologies for the modern world. Along with the others that have been re-devised, mud/earth has recently gained acknowledgement as a suitable technology for contemporary buildings. Africa as a tropical continent between the Atlantic (west) and Indian (east) oceans has over 5000 years of recorded history that shows buildings and monuments made of many natural materials available in abundance in its environmental landscape. Kriegler (2012) stated that given these challenges, prospects for connecting impact, adaptation and vulnerability research more frequently and directly with CC scenarios depends on three factors:

- ✓ Developing situational information that is relevant to concerns of this research, such as information about extreme weather events or improved information about precipitation changes.

- ✓ Stimulating knowledge development and cultural changes in the impact, adaptation/vulnerability research community so that relations with other parts of the CC research are viewed as a higher priority and as adding value.

- ✓ Developing decision-making approaches that understand but are not impeded by uncertainties in using scenario-based impact and adaptation results.

Babatunde and Olakunle (2014) suggested that in the late 18th and 19th centuries, the colonial administration brought with its 'civilization' and the construction of public buildings (schools/institutions, warehouses, banks, hospitals and courthouses) and residences. Relatively impressive places of worship were built. Construction was mainly timber framed and masonry structures raised well above ground, covered with corrugated iron, iron sheet and large well-shaded windows. Nigerian architecture evolved in this period as a relationship of local materials and expressions such as large overhangs and verandahs, plus elements, styles and symbols from the British became very evident.

Nwosu (2009) emphasized that architectural forms and the function of African traditional buildings depend on the following:

- Function of immediate natural environment in terms of form and style.
- Availability of local building material.
- Cost of materials (mostly free).
- Compatibility with the local environment (such as climate, geology and topography).

Each architectural form corresponds with the geographic zone. For example, the climate of humid coastal rain forest belt where there is little temperature change and between, dry and wet season, is usually in need of shelter with maximum cross ventilation to ensure comfort. In this region, rectangular houses, which are efficient at cross-ventilation. However, the savannah regions face a different challenge, where there is a larger seasonal change from almost -1.1-1.6 °C. To cope with these conditions, building designs in this region are built to withstand and protect them from high wind and low temperatures. It provides a cool interior despite the heat produced by midday intensive solar radiation for which the Sahara Desert is well known.

Clay walls help to concentrate thermal radiation within the interior of the building. The windows on the round huts are meant to maximize the thermal properties of the thick clay walls. The cylindrical buildings paradoxically have the same visual effect as the tall trees in the forest zones. The surface of the clay wall blends with the natural appearance of the surroundings and eliminates harsh contrasts.

As Hull (1976, p. 54 in Nwosu, 2009) observed "*popular magazines since the mid-nineteenth century have associated most traditional Africans with round, thatched-roof mud-walled huts*." Therefore, according to popular opinion, all pre-colonial Africans lived in circular mud huts roofed with grass or thatch. This view is misleading, as a variety of architectural styles, including rectangular, quadrangular and octagonal and a wide range of building materials, such as stone wood and clay, are of great antiquity throughout Africa.

Clay continues to be an abundant local building material throughout the continent. Nwosu (2009) agreed that some traditional Africa residential units, particularly the cylindrical ones, are poorly lit and inadequately ventilated. However, disagreed that the buildings constantly needed maintenance, stating that buildings of durable local materials, such as clay and stones do not require more maintenance than those of so-called modern materials, such as cement, glass and plywood. Critics of traditional building materials also tend to exaggerate the weakness of these materials when they claim that they are susceptible to termite attack. The strength of traditional building materials is especially amplified when examined against the backdrop of the so-called modern alternatives that have been proposed by governments and Western change agents throughout Africa (Nwosu, 2009).

2.8 Climate and socio-economic considerations

An important factor that determines the way the *Tivs* build is considered by De Wilde (2012) and Egbe (2014) to be the climatic characteristics of the area as well as the social and economic aspects of adapting to CC. The CC situation represents a significant environmental, social and economic threat which is now recognized by most governments and scientists as an issue of extreme concern.

In itself, the built environment is a significant contributor to greenhouse gas emissions. For typical developed nations, like the OECD countries, De Wilde (2012) suggested that 25–40% of anthropogenic greenhouse emissions is related to buildings, some 40–95% of these emissions will be caused by operational energy use, with the remainder caused by construction and demolition. Financial limits always exist on building environmental forces and are distinguished from economic ones on the basis that economics is to do with the deployment of resources, whereas financial limitations are strictly to do with money (Olutuah, 2014).

A challenging duty for any project manager is to ensure that a project is financially viable within a fluctuating economic environment (Odeh and Battaineh in Akianni *et al.* 2014) The periodic economic phases affect construction activities which require accurate forecasting of local and global economic trends (Oladapo and Olotuah, 2014).

Climate change impact and adaptation research deals particularly with uncertainties about an ecosystem's response to warming, the importance of value judgment in cost assessment, great heterogeneity in impacts and adaptive capacity, a need for local and context-specific analyses and long-range interactions through world markets (Kriegler, 2012). CC vulnerabilities and responses depend not only on changes in climate parameters and interactions between these parameters and changes over the same periods in local socio-economic conditions, such as population size and distribution, economic activities, technologies and institutions (Parry *et al.* 2007).

Kriegler (2012) stated that the treatment of climate policies in CC scenarios is controversial. In economic analysis, policies are generally evaluated against a counterfactual case. The counter-factual no climate policy case usually provides the reference scenario for integrated assessment models, which are then compared with a climate policy scenario. In contrast, impact/adaptation/vulnerability researchers have often used a reference present-day case as a baseline to compare with scenarios of future socio-economic and CC, which may include different sets of policy expectations. Lack of awareness about low cost energy efficiency measures is an issue for building adaptation (United Nations Environment Programme (UNEP), 2009).

Scovronick and Armstrong (2015) explored how housing modifies temperature–mortality relationships in the Eastern and Western Cape provinces of South Africa. They found that traditional dwellings were thermally superior to other low-cost options. Adunola (2014) suggested that indoor and outdoor air temperatures remain the dominant climatic factors affecting thermal comfort in the tropics. The afternoon period in the tropics is noted for discomfort due to the impact of intense solar radiation, leading to high air temperatures. This consistent impact of high insolation affects buildings largely dictates levels of indoor comfort. It has been established that buildings must provide a functionally acceptable thermal environment. The residential building in particular, as the home environment, should present a comfortable atmosphere suitable for its purpose as a place of rest. Tetteh (2010) reported that the way of life in Africa's rural settlements determines the types of dwellings built. Settled farming societies have different requirements to herding societies, which are usually nomadic. Other rural societies in Africa are based on farming, hunting and gathering in various combinations (Chanda, 2006, in Tetteh, 2010).

Agboola (2014) argued that Nigeria parades numerous traditional building design concepts in different climatic, socio-economic and cultural regions. Rikko and Qwatau (2011) referred to traditional forms of architecture as a cultural heritage gained from generation to generation. Therefore, designs in traditional architecture reflect the cultural lifestyle of the people and represent the symbols of the heritage of the residents.

Babatunde and Olakunle (2014) suggested that architectural forms could be seen as the art of designing buildings and structures for convenience for human habitation and utilization, considering factors such as the variation in norms and social comfort in different societies. The tendency in exhibiting these values and the character of life, coupled with factors such the materials available and the use of building, significantly suggest design. They also stated that architecture evolves and depicts the language the society in question. They argued that good architecture must satisfy three requirements in a user, that is his physical needs (satisfactory body reaction of feeling), his emotional needs (aesthetic and psychological) and his intellectual needs (logic orderliness and flawlessness). Hence the appeal to architecture to be both an art and science (Astrolabe, 2002 in Babatunde and Olakunle, 2014).

Ikejiofor (1999) suggested analysts agree that social norms and standards of physical planning and development control in the Third World are both strictly framed and are also culturally, socially and psychologically aligned. As they derive from industrialized Western culture, these norms and standards often emphasize on individual privacy and control of personal space and a lifestyle that revolves around indoor living, even in the tropical climates. Ejiga *et al.* (2014) argued that sustainability is linked to durability, stating that traditional African buildings have lasted for over 60 years and have proved themselves to be outstanding works of architecture that have stood the test of time but are cheap and comfortable, with little or no carbon footprint.

2.8.1 *Sustainability and materials considerations*

Rashid and Dilshad, (2015) stated that the selection of materials depends on their strength and properties. Thus, resultant size of the dwellings varies. The size of the public space, that is, the living space, may range from ~23 m^2 in a bamboo-built dwelling, to ~60 m^2 in a wooden dwelling. Thus, the material and its structural properties influence the size of the built form.

Ejiga *et al.* (2012) listed three well-defined materials that are popular in African traditional building. These are: stone, straw and earth which have been independently and jointly used and skilfully applied. Diverse areas, to a great extent, have used materials peculiar to them based on their availability and the developed technology of their artisans.

Various natives of Africa took to straw/thatch as a construction material in a comparable way choosing, to a great extent, the proper materials for the most suitable use. In contrast to stone, which is not easily renewed, straw/thatch is a by-product of local cultivated plant. Even though large quantities of this material could be sourced from the immediate surroundings and the wild, the villagers cultivated much of the straw as cereals in their farms which in turn, provided building material (Ejiga *et al.,* 2012).

Ellis and Freeman (2004) suggested that mud and thatch are particularly good heat regulators. They are materials with low thermal conductivity, which is an advantage in hot humid cities. The thatch allows air to penetrate the house slowly, therefore, regulating the indoor climates. The same roofing strategy is used for construction of the storerooms.

Olutuah (2009) reported that traditional house forms in Nigeria are an essential part of the traditional architecture of the various Nigerian tribes. They are built within the context of the communities and in accordance with their material, biological and spiritual needs. Building earth is the indigenous material for house construction in Nigeria (Olotuah, 2002b; Olotuah, 2005 in Olutuah, 2009). Houses of earthen walls and roofs are found predominantly in villages and some can still be found in the suburbs of cities. In Nigerian traditional architecture, earth construction takes three basic forms. Mud obtained by swish-puddling is mainly used in construction in the southern states, where clay is most common. Sun-dried mud bricks are used for construction in the north. Additives such as straw, hay and cow dung are mixed with the material to ensure that it is sufficiently cohesive. The third form is the use of fired or baked clay bricks. Other indigenous building materials include stone, timber and bamboo. Improved alternatives to indigenous materials are used extensively in urban areas and include cement stabilized blocks from laterite soils, bricks and blocks from mineral and industrial wastes, cement bonded wood and wood boards.

The first major step in storeroom construction is the obtaining of gable (special hardwood in Benue) from the near-by bush. This type of wood is very good for construction purposes, because it is termite-proof (Ogundele, 2007). It can withstand the vagaries of the environment for a prolonged period. The forked pieces of *'gbaaye'* (flexible) wood are used as granary stands after they have been neatly trimmed. The forked pieces of '*gbaaye*' are usually of equal lengths ranging from 60-100 cm. Some plain pieces of '*gbaaye'* are later arranged horizontally and then firmly tied to the stand (Figure 2.21). Mud is piled on this platform to create a floor of the construction work is often done by women and children. The thickness of this floor ranges from 10-15 cm. The thicker the floor the better with respect to durability (Bohannan, 1954, p. 20-30 in Ogundele, 2007).

A raised platform of a granary among the *Tiv* is a form of cultural adaptation to the challenges posed by the immediate environment (dampness) (Figure 2.13). The raised platform prevents dampness from the granary so that the stored grains can be preserved for a relatively long period.

Figure 2.13. Raised granary, (source: Ogundele, 2007).

The platform serves as a cage for such domestic birds such as chickens and ducks. A circle is inscribed on the floor before it hardens completely. It is done with a sharp peg tied to another one that is fixed at the centre. The length of the rope determines the circumference and hence the diameter of the granary. The plastering over of the platform with the prepared mud coupled with the mark of a circle on the floor represents the second step in the building of granaries in *Tiv* land (Ogundele, 2006, in Ogundele, 2007).

Well prepared mud is shaped into cylindrical lumps. The diameters of the lumps vary between 12-16 cm. This determines the thickness of the granary wall. This is called the coiling method of mud construction. According to available oral traditional and ethnographic findings, this method derived from the ancient pottery technology of the '*Tiv'.* The average height of the walls is 1.7 m. A small opening is created using stored. Some granaries do not have entrances, but rather the conical roofs are carefully removed whenever grains are needed (Ogundele, 2006 in Ogundele, 2007).

2.9 Climate change adaptation for building designers

Predictions for the future add the uncertainties of the biological and social sciences to the already large uncertainties from the climate models (Corlett, 2012). High natural climatic variability coupled with the paucity of long-term records in the tropics have so far made it difficult to detect the impact of CC (IPCC, 2014). Moreover, the impact of CC is expected to interact with that of other, more direct, human impacts, including deforestation. Thus, an architect who designs for climate change adaptation (CCA) should recognize that the nature of weather events is unlikely to remain the same throughout a building's lifetime.

Performance indicator monitoring and data are required in the evaluation process. Monitoring and evaluation processes depend on cautiously developed sets of indicators, by which the performance of adaptation activities can be assessed. These indicators provide the basis for 'before and after' analyses and define the positive and negative effects of project interventions.

2.9.1 *Risks*

1. More intense rainfall.
2. More frequent flooding.
3. More hail storms.

2.9.2 *Possible effects*

1. Greater intensity of runoff; issues of structural integrity; drainage; opportunities for capturing rainfall.
2. Sea-level rise leading to coastal and inland flooding; more coastal salt spray; water damage to building contents; contamination from sewage, soil and mud; undermining of foundations.
3. Impact damage (mostly roofs, guttering, windows) and subsequent rain/moisture penetration.
4. Greater fire risk.
5. Rising temperatures.
6. Impact on external surfaces; thermal performance of building.
7. More frequent / intense cyclones.
8. Greater strain on building material fixtures, claddings and fasteners; greater wind loading requirements.
9. More fire events.
10. Total or partial fire damage; smoke and water damage.
11. Mould; condensation; decreased thermal performance of building (Hallegatte, 2009).

Building flexibility into a design to allow for the unexpected makes investment decisions robust to most possible changes in climate conditions. (Snow and Prasad, 2011), They refer to one of the strategies as "*no-regret strategy*" that brings benefits even in the absence of future CC (e.g. strengthening tile fixtures securely to a roof to avoid wind damage, or polishing or tiling a concrete ground floor to allow quick recovery after floods).

2.10 Cost benefit of CC adaptation

Veneziano and Ballard (2010) suggested that in order to determine whether a practise, equipment and operation should be implemented requires cost-benefit analysis. This consideration includes tangible and intangible costs and benefits. Intangible costs and benefits are those for which a monetary value cannot be assigned. In the case of a winter maintenance practise, equipment and operation, it is more common to observe benefits for which a monetary value cannot be readily assigned.

2.11 Multi-criteria Analysis of climate change adaptation

Klein *et al.* (2014) stated that adaptation decision-making involves the reconciliation of legitimate differences about how adaptation resources are distributed and the values that adaptation seeks to protect. For example, the costs and benefits of different adaptation options, such as insurance schemes or large-scale infrastructure projects, may be inequitably distributed among different performers and stakeholders. Such inequities may generate ethical questions regarding who is advantaged or disadvantaged by adaptation actions.

Multi-criteria analysis proposes inclusion of a broad range of stakeholders and is frequently promoted in policy responses to CC (Shisanya *et al.,* 2015). It is a preferred method for this research, because it principally adds the sense of securing the active involvement of a broad range of stakeholders in decision-making and action. In addition, awareness that CC may exceed the capacity of dwellers to adapt may have ethical implications for decisions regarding mitigation and climate targets, as well as investments in greenhouse gas mitigation policies and measures. National and international law as well as decision-making at regional and local scales among both public and private participants will influence distributive and procedural justice in adaptation planning and implementation.

2.11.1 *Adaptation scale*

Typically, governments are responsible for making provision addressing many of the barriers to adaptation. This is because of their ability and responsibility to intervene and create opportunities, resources and policies to aid adaptation. Despite the importance of identifying opportunities for adaptation, there are not many studies focusing on how local government has facilitated experimental adaptation specifically, in a developing country context (Defra, 2010).

Climate change will have different impacts on dissimilar localities and communities across the planet. Marginalized indigenous people living in rural areas of the world will endure the effect of climate impact, while contributing very little to its cause (Green *et al.,* 2009; Tsosie, 2007; UNDP, 2007 in Maru *et al.,* 2014). They are of the opinion that it causes a common description about marginalized remote regions as being vulnerable to CC, a narrative which identifies both the intertwined nature of the global pattern of disparity with the causes and costs of CC and the role of CC as a multiplier of prevailing difficulties. Tang *et al.* (2010) added that political leadership, previous disaster experience and active engagement in CC related events have all been shown to impact on whether communities act on CC.

Campos *et al.* (2013) suggested that developing countries are more vulnerable to CC than developed countries, because extreme weather circumstances and their accompanying impacts tend to intensify existing socio-economic challenges. Developing countries usually face socio-economic problems of being unable to adapt. Shisanya (2015) suggested that old buildings responded to the weather, the economy and the people. He adds that the relationships and work patterns of rural people lasted longer than their buildings and their building patterns represented it. Butler *et al.* (2016) were of the opinion that one of the social challenges of adaptation in a developing country's responses to CC is the lack of integration of adaptation with cultural beliefs, which tends to bring regrets in using these strategies for the rural poor. They recognized that such subjects are scarce in the literature on how to achieve this. IPCC (2014) reported that CC is felt most acutely at the local level. Nordgren *et al.* (2014) added that in light of this, communities are starting to prepare for current and projected future CC.

To track their efforts, the adaptation community created a five-step climate adaptation process, that includes:

1) Identifying and assessing vulnerability and risk.
2) Planning.
3) Implementing strategies.
4) Monitoring and evaluation
5) Revising and sharing lessons learned (Bierbaum *et al.* 2014; Intergovernmental Panel on Climate Change, 2014; Moser and Ekstrom, 2010 in Nordgren *et al.,* 2014).

Bouchaira and Dupagne (2003) emphasized that modernization can have negative effects on the progress necessary to provide a pleasant way of life for some traditional people. They explained that planning and urban design processes and regulations applied by professionals and government agencies are based upon modern ideas imported from different cultures. This often contradicts some traditional practises. They recommended that planners and designers take traditional practise as a source of inspiration and make balanced integration between technological improvements and traditional practises, so that historic buildings and settlements are renovated without regrets.

Sarzynski (2015) identified that for more successful local adaptation options, government response is inevitable. He added that responses may be more readily obtained at local levels than at higher levels, given that fewer people that may need to manage collective action. Additionally, participation will produce a more effective adaptation plan by involving local stakeholders and specialists in the development of a national adaptation strategy, bridging the gap between the top-down and bottom-up approaches to adaptation.

The success of an adaptation approach depends on how the action meets the objectives of adaptation and how it affects the ability of others to meet their adaptation goals. Successful adaptation, therefore, depends on the scale of implementation and the criteria used to assess it at each scale. Therefore, adaptation approaches and scale will vary at local, national and international levels. In the built environment, adaptation strategies include building designs that withstand CC impacts.

2.11.2 *Public response to adaptation*

Fünfgeld (2010) reviewed the literature on CC adaptation and public response. He found that well-facilitated and active involvement of households and communities in developing and implementing CCA programmes is critical, because CC vulnerability is experienced locally and adaptive ability and actions are best monitored and realized locally. It is, therefore, imperative to research climate impacts as unique from one locality to the other. What works for one location may not work for another. Climate impacts/adaptation cannot, therefore, be generalized readily.

Isam (2017) identified the people most at risk from CC are those living in affected areas who:
• Are least able to avoid the direct or indirect impacts due to not having good quality homes and drainage systems that prevent flooding.
• Are infants and older groups less able to cope with heat waves and are least able to cope with the illness and injury to property caused by the impacts.

2.11.3 *Government response to adaptation*

Both at national and the local levels there is a special risk from CC faced by those with limited incomes. They look up to government interventions. In developed countries, government response may be quick and responsive. However, Islam (2017) identified that most local governments are weak and ineffective and often refuse to allow any public services informal settlements. He gave a challenge to receiving proper risk reduction action for lower income groups in any city. Referring to his interviews and discussions with individuals living in 15 disaster-susceptible slum communities in El Salvador and with local organisations he confirms the lack of government participation. He concludes that low-income households face flooding and landslides as the most serious risks to their lives and livelihoods.

UNFCCC (2006) suggested that governments may also need to change building codes while providing the housing and building sectors with appropriate information and education. This should be achieved through industry training schemes and supporting the construction industry through programmes of research, development and demonstration. At the same time, for these measures to be effective government also needs to strengthen the capacity of local authorities and enforcement agencies.

Maru *et al.* (2014) listed obstacles which often impede CC action, including:

- Difficulty in understanding climate science (Fünfgeld, 2010),
- Lack of staffing capacity (Aylett, 2015; Shi *et al.,* 2015; Thayer *et al,.* 2013 in Maru *et al.*, 2014).
- Limited financial resources (Anguelovski and Carmin, 2011; Hunt and Watkiss, 2011 in Maru *et al.,*(2014).
- Lack of leadership (Amundsen *et al.* 2010; Bedsworth and Hanak, 2013; Bulkeley, 2010; Measham *et al,.* 2011; Moser, 2009 in Maru *et al.,* 2014).

2.12 Effective adaptation

Ford *et al.* (2006) advocated that analysis of past and present experiences of responses to CC in communities can improve the way communities adapt. They use Inuit Canada to show how community members in Arctic Bay and Igloolik are responding to the CC. They concluded that there are indications of significant adaptive capacity, because the communities identify that responses are largely behavioural and include avoiding, minimizing and sharing risks (Figure 2.14). Many of these are strategies traditionally used by Inuit to manage climatic exposures that affect harvesting, but with CC, they are becoming increasingly important and are used more often. The ability of Inuit to cope or deal with CC is indicative of their adaptive capacity. This capacity is facilitated by Inuit knowledge and land-based skills, strong social networks flexibility in seasonal hunting cycles and economic and institutional support. Inuit knowledge (IK) and land-based skills contribute to the adaptability of hunting and harvesting livelihoods. From knowledge passed down the generations and from repeated personal experience and observations, hunters learn the inherent dangers of hunting, how to evaluate risks, what preparations to make before hunting and what to do in emergencies. A repository of accumulated experience and knowledge of changing conditions and successful adaptations are drawn upon both to maximize hunting opportunities and to minimize risks.

2.13 Adaptation and the total costs of climate change impacts

2.13.1 *Adaptation costs*

In relation to limited financial resources (Anguelovski and Carmin, 2011; Hunt and Watkiss, 2011 in Maru et al., 2014), Isam (2007) reported that generally wealth allows individuals and households to risks by having safer homes and choosing safer locations to live in. He added that for most in Africa, Asia and Latin America "*low income groups not only live in settlements with the worst quality housing and least provision for drainage but also in the districts most at risk from floods and landslides*" (Isam, 2007). The unsafe sites are regularly the only sites where lower income groups can find accommodation.

Fankhauser (2009) investigated the history of CC adaptation costs. His objective was to refine the general understanding of CC impacts. Recognizing that impact estimates would be wrong if they did not include an adaptive response and overcame the assumption that there would be no reaction to a change in climate, in a survey of adaptation in impact models. Tol *et al.* (1998) in Fankhauser (2009) concluded that many impact categories covered in the economic cost literature were actually adaptation costs. In particular, these were coastal protection, defensive expenditure for air pollution control and in some cases migration.

2.13.2 *Communities' awareness of adaptation strategies and cost*

Understanding adaptation cost must be considered within larger context, as adaptation is only one part of the overall response to CC (Fankhauser, 2009). The total burden of CC consists of three elements: the costs of mitigation, the costs of adaptation and the residual impacts that can be neither mitigated nor adapted to. For example, society may seek to limit the overall temperature increase to 2°C (mitigation), invest in coastal protection to limit the negative impacts of 2°C warming (adaptation) and accept the loss of certain coastlines, because they cannot be defended at reasonable cost (residual damage) (Fankhauser, 2009).

Another important delineation is between adaptation and socio-economic development. Socio-economic trends over the coming decades (population growth, economic expansion, the deployment of new technologies) will affect our vulnerability to climate events and indeed may be shaped by climate conditions. It is difficult to delineate where socio-economic development ends and adaptation to anthropogenic climate change begins. This is particularly the case for developing countries, where there is a well-documented adaptation deficit, that is, insufficient adaptation to the current climate. Poor people and poor countries are less well prepared to deal with current climate variability than richer people and richer countries. There is evidence that higher measures of development indicators such as, income, literacy and institutional capacity are associated with lower vulnerability to climate events (Noy, 2009; Bowen 2009). This led Schelling (1992) to conclude that good development is one of the best forms of adaptation. McGray (2010) identified a continuum of measures that address, both development and adaptation needs. They range from measures that reduce vulnerability to stress more broadly (whether climate-related or not) to the creation of „*systems for problem solving*" the management of current climate risks and policies specifically addressing CC. Most cost estimates deliberately and understandably ignore the overlap between adaptation and development and focus on incremental adaptation over and above a vaguely defined baseline, that includes climate-relevant development programmes. With caveats must be considered in reviewing adaptation cost estimates.

Carley (2007) investigated the sustainability of earth architecture in Uganda. He evaluated earth building techniques of adobe, wattle-and-daub and Compressed Stabilised Earth Brick (CSEB). He compared these to conventional fired brick. Using a multi-criteria analysis approach and ideas from systems theory, he evaluated four techniques in terms of social, economic and environmental sustainability criteria. The comparison revealed that, for the same architectural quality, the wattle-and-daub and adobe techniques are more sustainable than brick, because they contribute to easing of poverty and improved socio-economic conditions and fewer environmental problems.

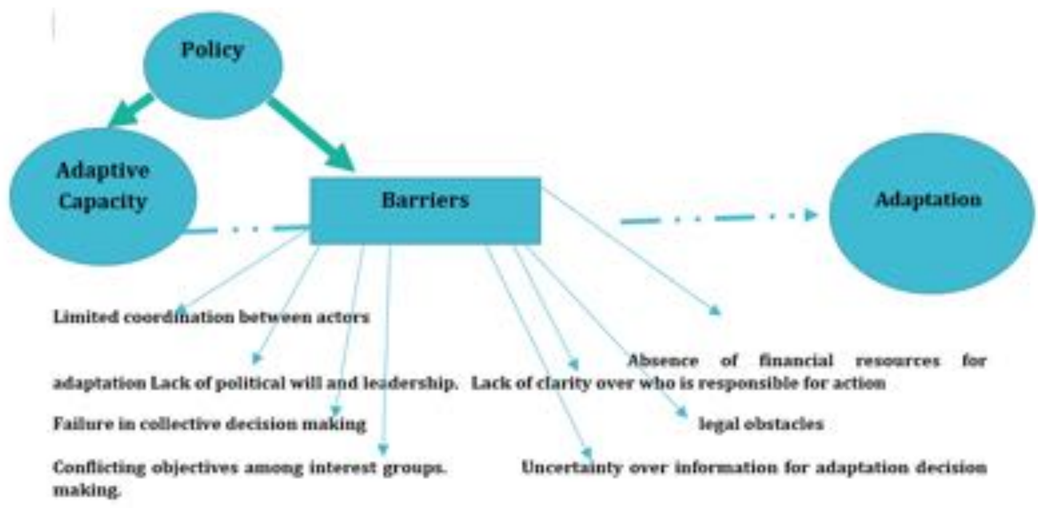


Figure 2.14. (Conceptualization of relationships between adaptive capacity and adaptation in an adaptation readiness framework, (source*:* Ford, 2015).

2.14 Adaptation strategies in relation to temperature

2.14.1 *Housing design*

There are multiple factors associated with building in a temperate climate (Brunsgaard *et al.* 2012). Seasonal temperature differences require specific environmental approaches to the designs in building, because buildings have to be adaptable to different situations. It is necessary to monitor seasonal climatic conditions in the conception stages of the design process and include these in the design brief.

A building design brief should address the comfort requirements for temperature, daylight, sound and ventilation, as well as the social needs of the user. The weather conditions also influence the success and selection of design strategies for the applied design principles. Once the climatic conditions are established, design strategies for how to ventilate the building and achieve and avoid external heat gains, can be developed. Design principles that are generally associated with the issue of achieving and avoiding external heat gains in temperate climates include:

1. Window areas and orientation (heat gain from the sun) (Figure 2.15).
- Seasonal shade (heat gain from the sun).
- Insulation of the building envelope (temperature differences between indoor and outdoor temperatures).
- Reduction of thermal bridges (temperature differences).
- Surface-to-floor area ratio of the building shape (surface area exposed to temperature differences).

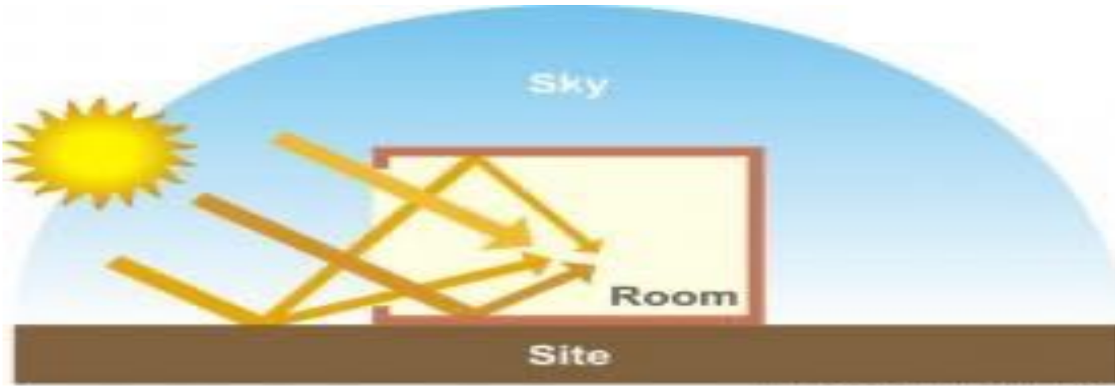


Figure 2.15. Day light Strategies, Utilization of daylight Compliance with BREEAM, (2010).

- Air tightness of the building envelope (control of air flow).
- Ventilation strategy (natural, mechanical and thermal mass activation).
- Zoning.

Selection of an energy-efficient ventilation strategy in relation to seasonal change is imperative (Brunsgaard *et al.*, 2012). The strategies applied in relation to these principles are determined by the seasonal variations of external air temperatures, wind speeds and directions, solar angles and azimuths and the type of building and its architectural concept. Four factors affect heat accumulation in a home: solar heat gain, internal heat gain, air leakage and temperature differences. Fordham (2000) suggested that buildings should be designed with controllable ventilation not preventing air and daylight as in Figure 2.16. A very high range of natural ventilation rates is necessary, so that the heat transfer rate between inside and outside can be selected to suit conditions. Ventilation rates are selected to control temperature, pollution and air movement. Ventilation with heat reclaim and the thermal capacity of the building must be considered. Buildings need to be designed with natural ventilation in mind, to minimize the use of fossil fuel energy.

Figure 2.16. Existing unmodified hut in Benue State, (source: author's photograph, 2015).

2.14.2 Strategy 1: Lighting in relation to maintaining temperature and cost

According to the US Department of Energy (2008), windows positioned towards sun rise and sun set will maximize daylight and avoid the use of fossil fuel as a source of light during the day. They suggested the option to control the amount of sunlight/air that comes into the building is the use of rolling shades made of fabrics. However, they are the most expensive shading options, but they work well and can provide security. Many exterior rolling shades can be conveniently controlled from the inside.

Mangkuto *et al.* (2016) regarded windows to be one of the most important building components. This is because they positively influence the health and well-being of building occupants. The design of the window tends to shape the overall energy demand in the building. They noted that contradictions frequently occur when trying to maximize daylight penetration and view, which typically means applying large windows, while trying to minimize energy consumption, which usually translates into applying small windows. They concluded that to attain thermal comfort in cooling applications in the tropics, buildings are designed to minimize daytime heat gain, maximize night-time heat loss and encourage cool breeze access when available. For breeze collection, window design is more important than direction, with louvers 95% opened to air as an option. The modelled hut uses this concept.

2.14.3 *Strategy 2: Using trees as shading*

Shading can reduce indoor temperatures by as much as 11°C (US Department of Energy, 2008). Effective shading can be provided by trees and other vegetation and exterior or interior shades. All walls and windows are permanently shaded to restrict solar access and rain. Outdoor areas are shaded with plantings to lower the ground temperature, causing the temperature of the incoming air to be cooler.

2.14.4 *Strategy 3: Block sizes*

In hot regions, building thick block houses and courtyards excludes hot and dusty winds. Thick walls serve as insulators against hot air.

2.15 Strategy 4: Building to adapt to flood

Eakin *et al.* (2016) surveyed a rural community in Mexico and reported that during the rainy season, 66% of participants said that usually, they experience flood impacts in their homes. Some 75% of participants considered that flooding always or almost always affects their surrounding streets.

BBC Local (2004) reported that Bangladesh, a low-income country with inadequate funds to implement large schemes, will always be threatened by flooding, so the focus is on reducing the impacts. The Flood Action Plan is funded by the World Bank and funds projects to monitor flood levels and construct flood banks/artificial levees. More sustainable ways of reducing flooding include building coastal flood shelters on stilts and early-warning systems. Eakin *et al.* (2016) identified that sometimes the problems of adapting to CC can be complex, knowing that opinion of comfort is greatly reliant on many aspects and parameters, which can also be contradictory in themselves. This study encountered the conflicting need for lighting and cooling.

Other important problems in adapting traditional housing in tropical rural communities include:

- Air quality.
- Communities' awareness of adaptation strategies and costs.
- Choice of construction material.
- Adaptation capacity.

Quagrainea and Boschi (2008) identified the main sources of indoor air pollutants in tropical environments as burning of kerosene, candles and mosquito coils. They stated that in rural areas where their inadequate electricity supply, kerosene lamps and candles are used for lighting and mosquito coils are burnt indoors. Burning in enclosed spaces without adequate ventilation leads to higher concentrations of carbon monoxide, nitrogen oxides and suspended particulate matter. Identified outdoor pollutants include dust and fumes. Sources of indoor pollutants include indoor smoking, congestion, building materials and indoor cooking. Sources of dusts and fumes within the outdoor setting are unpaved roads, automobiles and the Harmattan winds.

2.16 Examples of rural traditional buildings in the tropics

Cases of countries with similar weather and building types were studied to obtain a wider perspective on traditional building types, successes and motives.

2.16.1 *Burkina Faso*

Quiros (2014) documented the process of building an African traditional hut in Burkina Faso in two stages:

Stage one

Water is mixed with sand and clay and kneaded; the mixture is used to make rectangular blocks, which are arranged horizontally from outside inward (Figure 2.18). Between each block the mixture of clay and sand is used to bind them. It takes six days to achieve the round shape of the hut.

Stage two

More mud is brought by the village women and mixed with water. The most important ingredient, cow dung, is then added to the mixture. When mixed with mud, the cow dung maximizes the adhesiveness of the mud with its rich fibres. The mixture is locally called “*banko*”; and is used as a natural cement. Usually women in the community use their hands to plaster and smother the walls by rubbing (Figure 2.17). Some women with special artistic skills engrave animals worshipped by local people into the plastered walls. The two common ones are the crocodile which is worshipped as the god of water, and the boa snake, which is worshipped for taking away diseases and problems. The house is usually built over a period of 20 days.

Figure 2.17. Rural dwelling in Burkina Faso, (source: Quiros, 2014).

2.16.2 *Bengali traditional building*

- Bamboo is a common building material for traditional construction in most of South-East Asia, where nearly half of the more than 700 species of bamboo known worldwide can be found (Rashid and Dilshad, 2015). In tensile strength, bamboo outperforms most materials, including reinforced steel. The strength the bamboo is achieved by its hollow, tubular structure. The lightweight structure makes bamboo easy to harvest and transport. Due to its extremely rapid growth cycle and ability to grow in various areas, bamboo is an economical construction material. Bamboo structures have high endurance against storms and earthquakes, which are very common in much part of Asia. Some other advantages of bamboo are:Bamboo produces no waste.
- It is a sustainable organic material that requires little labour to harvest.
- Bamboo can be sliced and flattened with simple of tools.
- The shell can be chopped into suitable lengths.
- Bamboo can be split to produce culm and split-peeled, to make binding and lashing materials.
- Bamboo splines can be woven to make partitions that are capable of breathing and screens that permit diffuse light.

A disadvantage of bamboo is its' vulnerability to buckling and limited resistance to wet soil. However, sophisticated methodological details in bamboo have been worked out to perfection in *Mru* architecture and reflect the adaptability of *Mru* building practises to their native landscape, climate, topography and available means and tools (Dilshad and Rashid, 2003 in Rashid and Dilshad, 2015). One adaptive measure is using hard wood to form the foundation that raises the main building away from the soil (Figure 2.18).

Figure 2.18. Bamboo rural housing in Bangladesh (source*:* Basu, 2013).

2.16.3 *Ghana*

Ghana has introduced mechanized methods of producing clay blocks for building to reduce the cost of labour in the construction of traditional buildings. The machine produces 180 blocks an hour, which are strengthened by hydraulic pressure. Dylov (2012) posted a YouTube video showing the easy steps to build a traditional building in the tropics that is adapted to the local climate. An average house in rural Ghana such as Appraponso and Bomba is ~50 m^2 in area. The local soil type is 80% clay (Dylov, 2012). Key adaptive features of the building are:

- An extended/overhanging roof to stop the sand from washing off the wall over time (Figure 2.20).
- Perforation on the wall to allow light and ventilation.
- The use of cement on the base to stop water retention.
- Soil spread on the floor and mixed with water to make a smooth finish on the floor.
- To ensure bricks stays in place, a special curved window shape is designed.

Figure 2.19. Adapted traditional building in Ghana, (source: Shepard, 2015).

2.16.4 *Nigeria*

In the most of Nigeria, especially in the south, bamboo is a core component of traditional building. Certain points are identified as the pillars to support the building and the bamboo is tied over the pillar in parallel manner (Figure 2.21b). Mud is then made into a ball-like shape and filled in-between as is Figure 2.21d). The mud is also used as a plaster over the balls for a smooth finish.

The *Tiv* traditional hut materials are very similar to the Ghanaian traditional building. An average size traditional hut of the *Tiv* people is made of clay. It is 4 m tall and 4 m wide with a 3 cm deep foundation. The block size used for the construction of the hut is 15 cm tall with 12 cm wide blocks. A typical type has one window of 28.4 cm. The roof is usually thatched and is typically replaced every four years.

Some of the common issues with the existing traditional hut "Ate" are:

- Low light levels.
- Dampness.
- Flood prone.
- Temperature fluctuations.
- Cracks.
- Impact from rain.

Figure 2.20. African traditional building in Nigeria, (source: Dylov, 2012).

Usually more mud is caved at the base of the '*Ate*' to stop flooding. This is usually ineffective as mud is easily washed away by continuous contact with water. Barb (2006) reported that in '*Siwa'* town it is common to see long cracks in the modern mud brick homes which makes it clear that repair is not an option (Figure 2.22). He said "*tearing them down and starting over is the only sensible thing to do"*. He further stated that cracks were a common concern in mud houses, which is why ancient Anatolian Catal hoyuk levelled their mud brick homes every ~100 years and built a new one on top of the growing pile, gradually raising the city up on a human-made hill.

Studies on the impact of CC in the tropics are relatively few in number (Ravindran, 2013). He further mentioned that previously, specialists reasoned that since CC was sudden at the poles, arctic and alpine species in those areas would be hit first and hardest before regions further away. However, in recent years, an increasing number of researchers have recognized the urgent need to assess the damage that is already underway in the Amazon, the cloud forests of Costa Rica and the tropics.

Figure 2.21. Lengthy cracks in the modern mud brick homes, (source: Barb, 2006).

2.16.5 *Brief history of study area: Benue State, Nigeria*

Benue State was created in 1976 and is located within the Lower River Benue trough in the middle belt region of Nigeria. The National Population Commission of Nigeria (2006) census reported the population as 4,253,641. Its geographic co-ordinates are 7°47'-10°0'E, 6°25'- 8°8'N (Benue State Government, 2014). Based on Koppen's Scheme of Classification, Benue State lies within the AW Climate and experiences two distinct seasons, the wet/rainy season and the dry/summer season. The rainy season lasts from April-October with annual rainfall in the range of 100-200 mm. The dry season begins in November and ends in March. Temperatures fluctuate between 23-37°C in the year.

Climate records from the tropics are under-represented in many studies, in particular records from continental Africa, the largest tropical land mass (Burnett *et al.,* 2009). Yet understanding how Africa responds to external climate forcing, as well as how it behaves distinctly, is imperative to the development of accurate models of global climate. It is therefore imperative to gather data that can be used to measure climate impact and the means to counter these impacts. In this research, a model to adapt traditional African dwellings to climate impacts is produced using Benue State as a case study (Figure 2.23). The cost of adaptation then compared to identify the benefits of adaptation.

Figure 2.22. Map of Nigeria showing the location of Benue State, (source: Onumba, 2014).

2.17 Key Points of the literature

2.17.1 *The lack of research on climate impacts in Nigeria's tropical savanna*

While there are reported of many attempts by environmental agencies to mitigate CC, there are fundamental issues with regard to adaptation. For instance, Yau and Hasbi (2013) suggested that at present most buildings in Europe are designed to utilize natural ventilation rather than mechanical ventilation (such as central air conditioning units and ventilators) as a means of reducing environmental impacts and operating costs. They further suggested that this situation is gradually changing as energy consumption related to heating, ventilation and air conditioning have been increasing throughout Europe.

Several authors have reported that lack of empirical evidence makes it difficult to measure and predict the impacts of CC relative to other extinction drivers such as habitat loss, invasive species, disease and over-exploitation. Sodhi *et al.* (2011) particularly drew attention to the issue of insufficient data in this area. With rapid changes in tropical landscapes as human populations and economies grow. "*Tropical forests also have a disproportionate role in global carbon and energy cycles and support 50% of described species and an even larger number of species not described. An understanding of anthropogenic change in tropical forests is thus crucial to understanding global CC and the conservation of natural habitats*" (Wright, 2005).

Sedjo and Roger (2007) suggested that throughout the 21st Century, CC impacts are projected to slow down economic growth, make poverty reduction more difficult, raise further threats to food security and extend existing and create new poverty traps, particularly in rural areas, thereby further developing concentration of hunger. Vogel *et al.* (2007) reported a clear gap between researchers and users, and disputed that the exchange is merely a matter of transferring specialty knowledge to various target groups.

Climate change impacts are expected to aggravate poverty in most rural areas of developing countries and create new poverty pockets in countries with increasing inequality, in both developed and developing countries. In the rural areas of tropical regions, such as Benue State where agricultural activities account for as ~70% of incomes, CC is bound to significantly impact on the economy. Extreme temperature events will become more common in the future and make climate impacts difficult to cope with (Singh *et al.,* 2014; Gosling *et al.* YEAR?; Miller, 2014; Wilson *et al.,* 2019). Harisi *et al.* (2011) reported that impacts of CC on tropical biodiversity is a subject of active debate and global reviews show that CC is having increased effects on biodiversity. They accord with Sedjo and Roger (2007) that studies tend to focus on temperate environments, with little attention to changes in the tropics (Laurance *et al.,* 2011; Wormworth and Sekercioglu, 2011, in Harisi *et al.* 2011). The study quoted Rosenzweig *et al.* (2008) stating that "*of the 30,000 studies reviewed for the IPCC 2007 Report, less than 1% were from the tropics*." The lack of research on climate impacts on tropical biodiversity, combined with the perception of a small overall degree of projected temperature and rainfall changes has tended to exacerbate the situation" (Harisi *et al.,* 2011). The lack of research in the tropics continues to constitute difficulties as tropical dwellers often have little information on how to cope with the changes and the decision-makers have insufficient information on what steps to take in response to CC.

Foster (2001) argued that one of the issues around CC lies in distinguishing between local and global CC. "*Changes in the global climate will cause changes in local circulation patterns.*

*Furthermore, local climate is likely to be affected by local events such as deforestation. While local changes may be much stronger than global ones at a given site, generalizing local changes is difficul*t". Figure 1.1 shows that even within neighbouring areas, CC impacts vary significantly.

Franchito *et al.* (2011) argued that studies investigating the relative roles of future greenhouse gas concentrations and future changes in land cover due to tropical deforestation suggest that CC at the regional level due to large land cover changes may be more than due to greenhouse gases alone. However, globally, the impacts of greenhouse gas concentrations seem to dominate over the impacts of land cover change (Franchito *et al.,* 2011).

The University of Miami (2013) emphasized the global dimensions of the impact of CC by pointing out that dust clouds from the Sahara Desert sometimes travel thousands of kilometres across the Atlantic Ocean. The study pointed out that in a recent study at the University of Houston and Arizona State University, researchers found that the average air concentrations of inhalable particles more than doubled during a major Saharan dust intrusion in Houston, Texas. This underlines the fact that local impacts of CC often have global effects and that though impact needs to be tackled locally, ultimately their effects are global.

2.18 Analysis of *Tiv* traditional architectural form

The architecture of residential buildings should collaborate with nature to enable harmony with their surroundings (Adunola, 2014). The idea of human shelter is the provision of building spaces that offer protection from uncomfortable climatic conditions and facilitate various human activities. Buildings modify climate and influence human behaviour and culture. There is a little literature on the study area and vital information is lacking, as the primary survey reveals. Olotuah (2014) reported that since the major drive of architectural education is the attainment of a humane and responsive environment, its re-positioning to enhance housing provision in Nigeria is imperative.

Ade's (2004) view of functionality in traditional houses responding to their primary role to shelter man and adapt climatically to his environment is correct, but vague, as climate is dynamic. Therefore, to effectively adapt to the present climate, there must be forecast on future impacts. Adaptation to CC is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects (IPCC, 2014). CC adaptation aims to mitigate and develop appropriate coping measures to address the negative impacts of CC on man, animals and vegetation. Adaptation to CC variability is not new, but CC is expected to present intense risks, new combinations of risks and potentially grave consequences. Adaptability to CC will be a relatively lesser problem in developed nations as a result of high level of technological development and high income (Odjugo and Osemwenkhae, 2011). This means that there is already a challenge of adaptation in the case study area, as the income of the populace is typically low. In general, the major social factor for the form of architecture in the area is the polygamous nature of the men. A typical *Tiv* compound will usually have each wife in her room with her children and the man has a room to himself. The desire to have many children is for their help on the farm, which is normally large and proportionate to economic yield. Active and passive spaces created in the courtyard allow many activities to take place and to take advantage of climatic situations in different seasons of the year (e.g. water harvesting of rain).

It may become necessary to promote the construction of such earth structures, especially as single-storey dwellings. The potential that lie in mud bricks, stone and straw bale may also need to be combined with modern technology to produce a new generation of homes that require no mechanical air-conditioning during hot days and cool nights.

2.18.1 *Implications for climate change*

With growing global concern about CC, the building industry is facing the question of how forecast changes in climate will impact on the performance of buildings around the world. This is resulting in a fast-growing field of research that focuses on the adaptation and resilience of buildings to CC. Ejiga *et al.* (2012) stated that developed countries, known as 'Annex 1 countries', are bound legally to targets for cutting greenhouse gas emissions. In total, these cuts seek a minimum 5% reduction in the 1990 level of all Annex 1 emissions before the end of a first commitment period in 2012. The built environment makes substantial contributions to the degradation of our environment. "*Buildings including construction, operations and deconstruction impacts, use approximately 15% of the world's fresh water resources; 40% of the world's energy; producing about 23-40% of the world's greenhouse gas emissions*" (Gunnell, 2009 in Ejiga *et al.,* 2012).

De Wilde (2012) suggested that the impact of CC on buildings is deeply connected to consequences for the building occupants and essential processes that take place in those buildings. As buildings have different functions, CC impact assessment studies must be tailored towards their specific needs and requirements. Complex interactions exist for instance, between the comforts as experienced by occupants, control settings in the building and energy consumption of heating and cooling systems.

Tunley (2011) argued that over-consumption of wood, branches and grasses, traditionally used as building materials in Benue rural areas, have had two effects of diminishing natural resources and increasing material cost. Building in the traditional manner can thus damage the environment and the scarcity of wood and grasses has unavoidably led to the use of low-quality material, with repercussions on construction quality.

Kriegler *et al.* (2012) described that a comprehensive exploration of integrated scenarios of mitigation, adaptation and residual climate impacts will require significant contributions from climate modelling, integrated assessment modelling and impact/adaptation/vulnerability research. To date, the problem is too complex to achieve such comprehensive integration within individual cross-cutting studies, although such studies will be of great value for fostering an integrated view of mitigation and adaptation. Therefore, integration will have to rely on a multitude of parallel studies from different communities. The obvious question is whether integration of studies would be feasible if their underlying assumptions are not harmonized.

2.19 Economic advantage of availability

Presently, climate models agree that there will be change and that this change will vary significantly from place to place, but they disagree on the magnitude of that change and they are not able to tell us exactly what form that change will take at the local level (Royal Society, 2010 in Levine *et al.,* 2011). The uncertainty on the magnitude of change makes awareness imperative at all levels. The present a sustainable solution on man's survival on the earth hinge on the option of knowledge of CC and adopting mitigation and adaptation measures and best practises. This is because awareness imposes responses for effective mitigation and adaptation measures (Gbetibouo, 2009).

The traditional forms of West African architecture and planning can, at first glance, appear primitive, but on deeper investigation it is evident that in many cases, these forms of architecture serve very functional purposes, something often lacking in contemporary West African cities. Traditional houses in the tropics are more concerned with the fundamental climate and provide comfortable interiors by the choice of building material. A typical traditional building of earth maintains a high level of internal thermal comfort, regardless of ambient solar radiation. Global temperatures are expected to rise in the next decade in the tropics due to increased levels of greenhouse gases (GHGs) from global warming. It is observed through a primary survey that vital information on the socio-economic aspects of *Tiv* architectural form is sparse. Such social information includes the polygamous nature of the *Tivs* and the number of children the populace wants for the purpose of large cultivation and harvesting on the farms (economic benefit).

Although there are arguments on how sustainable the traditional material of the *Tivs* is, based on tree cutting and grass cultivation, it should be noted that these materials maintain their natural states as they are untreated. These natural and native materials in housing delivery in *Tiv* traditional building have an economic advantage of availability. The thesis discusses the relevance of local inputs to affordable housing with an overview of the tropical architecture and evolution of traditional tropical architecture to modern tropical architecture. Traditional architecture entails architecture that appears to be traditional because it bears certain formal resemblances to traditional vernacular architecture and it is often constructed from similar local construction material, such as tropical hardwood and mud. It is postulated that the successful fusion of traditional materials and modern technology will sustain a decent lifestyle and liveable neighbourhoods in rural communities. It will also encourage good building practise through the art of green building and probably reduce the total cost of a building.

Stern (2007) argued that it is almost settled knowledge that the global climate is changing in remarkable ways. Adaptation and mitigation for CC are a global challenge, the effectiveness and sustainability of adaptation and mitigation strategies in any one nation or group of nation states is highly dependent on those pursued elsewhere. There is much scope for the impacts of CC to be displaced, leading to an unbalanced distribution of environmental and social costs and benefits. As such, the governance of CC is both a global and a local issue. While CC and climate modelling are subject to essential uncertainties, it is clear that human activities have powerful roles in influencing the climate and the risk and scale of future impacts (Smith and Plifosova, 2003). Scientists of various backgrounds agree that if current emissions levels continue unabated, the world will soon experience a radical transformation of its climate. There is, therefore, an urgent need to measure the present impact of CC both at local and regional levels, to enable design appropriate adaptation and mitigation measures.

The universal optimistic challenge of providing housing for all calls for a re-evaluation of current strategies of housing production. One approach is to use the wealth of knowledge skill and experience in traditional Nigerian residential architecture may be useful in addressing contemporary urban low-income housing problems. With slight modifications to existing development control standards, the traditional compound house built on the courtyard principle offers a solution with some potential to improve the quality of both rural and urban low-income housing, while alleviating some of the bottlenecks inhibiting the supply of such housing. Therefore, this house form could be a veritable resource for policy-makers in the quest for enhanced quality and quantity of low-income housing in Nigerian cities.

Having such a degree of potential, traditional African architecture, particularly building with mud bricks, is worth investigating. There are overwhelming benefits of using local materials and possible integration of building methods into housing delivery in Africa, especially in Nigeria. This is achievable only by close study of the forms and functions of architectural designs that exist in the study area.

In adapting buildings for CC, the key consideration is that what may be a good adaptive feature for one indicator may be directly opposing another dependent feature. For example, the bangle building which stands on wood foundations and allows the free flow of water through without having direct contact with the building avoids flooding to a large extent but is a feature which cannot be used if high winds are persistent.

2.20 Successful cases of adaptation

2.20.1 *Success case 1: The case of Durban, South Africa*

The case of Durban, exposed to both flooding and coastal erosion, explaining the importance of developing traditions that focus on social justice and exposure in order to achieve sustainable adaptation is viewed as an option for sustainable adaptation (Brown and Siri, 2012).

According to Aldunce *et al.* (2007) some characteristics of successful adaptation include:

- Prioritizing the needs of vulnerable groups in both development and climate policy processes and addressing adaptation concerns at the local level.
- Developing plans that are concentrated on the need to address the social discrimination created based on economic class, but with little connection to general CC impacts (Robert, 2008; Carmin *et al.,* 2009).
- Engaging communities with what is of concern to them and creating response options (Robert, 2008). Not only might the benefits of susceptible groups be heard but also the understanding of the implications of CC in the local context was enhanced, breeding local interest and policy action (Vogel *et al.,* 2007).

The situation improved when programmes concentrated more precisely on exposure and climate protection, such as organizing a vulnerability assessment. This assessment served as an opportunity to engage different community stakeholders in CC discussions (Carmin *et al.,* 2009) leading to acknowledgement of the communities' exposure and of existing advantages through which adaptation could be aided. It also required that such processes consider and recognize different interests and potential value clashes and categorize their impacts.

2.20.2 *Success case 2: The case of Norway*

2.20.2.1 The importance of implanting long-term local actions and adaptation

Consideration of CC as a global concern is illustrated in the case of snow-dependent leisure activities in Oslo, Norway. For local adaptation efforts to be considered sustainable there is the need to consider the following:

- The global effects of these efforts. They gave the instance of using low-energy adaptation options rather than high-energy adaptation options as they limit GHG emissions that add to global warming and increased risk elsewhere.

- Long-term plans for options to be considered. Vogel *et al.* (2007) gave an example of how recreational activities such as winter sports and leisure activities like skiing and skating are ingrained in the Norwegian national identity, but have lately decreased due to a warming climate. Ways of defining national identity may now have changed due to the absence of long-term plans (Robinson and Herbert, 2001). They observed that adaptations in the appearance of warming environments focus on preserving current activities through 'controlling' local environmental conditions in the short-term and sometimes in ways that involve increased energy use. For instance, the production of artificial snow ice in some municipal authorities and sports club in the West may lead to increased traffic, noise, light pollution and increased emissions from the energy used in producing artificial ice.

2.20.3 *Success case 3: The case of Chile*

2.20.3.1 Building local knowledge and capacity in risk reduction in Concepcion´, Chile

In the case of Chile, a very practical example of education or creating awareness at the local level is considered**.** The significance of present local data and capacity is principally well exemplified by the case of Concepcion, Chile. Where exposed, people have established responses to disasters based on their information and understanding of the environments (Aldunce *et al.,* 2011). They observed the community of *Agu¨ita de la Perdiz*, which consists of mainly casual and prohibited dwellings, built on landslide-prone areas on the 'Caracol Hill. The area experienced climate-related hazards, such as rainfall and cyclones, which are expected to increase in frequency and magnitude because of CC. They reported an incident in 2005, where the community living in *Agu¨ita de la Perdiz,* faced the most severe event in 142 years when 162.2 mm rain fell in 24 hours and cause massive damage to property with 100 out of 282 houses partly or totally destroyed (without deaths, only minor injuries). When an in-depth interview with people affected was conducted, it was discovered that a vital aspect that helped to protect their lives was the knowledge people had of their environment and exposure (Aldunce *et al.,* 2012).

Rather than waiting for external warning and help, people organized a refugee camp, evacuated vulnerable community members and took turns to protect houses against robbery (Aldunce *et al.,* 2012). Confronted with recurring extreme events, the *Agu¨ita de la Perdiz* community has shown itself skilled at producing social education and the population has a high level of risk awareness and knowledge about the physical environment and potential vulnerability (Eriksen *et al,.* 2005; Eakin, 2006; Vogel, 2006; Ziervogel *et al.,* 2006).

2.20.4 *Summary of Chapter 2*

It is clear that studies regarding CC adaptation need to be context-specific. Although current understanding of how to engage people to reduce carbon emissions is limited, it does suggest that achieving a motivation that has an internal nature will be more effective and of more value in the long-term, than motivation with a solely external focus. The self-determination theory developed by the psychologist Ryan (2015) is a well-established motivational model and specifically describes an extrinsic type of motivation with an internal nature. A sample group who have a reportedly strong internalized motivation in the climate context is selected for this research. By studying the mental characteristics of such participants, it is possible to improve the understanding of the personal traits and the processes that enable such behaviour and of the type of people who have reportedly overcome the barriers to adaptation and mitigation action that previous research has identified and minimized the gap between intention and actual behaviour in CC adaptation. Thus, constitutes the first and second aims of this research. Improving understanding of how concern translates into behaviour in the climate context and, in particular, the associated actual-intention gap is critical in promoting individuals to engage in adaptation. Study of the defining characteristics and the mechanisms for their development should throw light on what underpins motivation to reduce CC risk and improve adaptation as well as what drives motivation to a higher level.

CHAPTER 3 : RESEARCH METHODOLOGY

3.1 Introduction

This Chapter describes the procedure and methods used to gather and analyse data for the purposes of this thesis. Based on the conclusions from the literature review, it was argued that a mixed methodology approach is most appropriate in examining the contextual determinants and dimensions of public understanding of and response to CC. This is because it seeks to retrieve information on a way of life, behavioral patterns and a community's historic approach to shelter through survey observations, semi-structured interviews, questionnaires and the construction of a modelled traditional hut adapted to CC. The construction is to enable a comparative analysis of temperature, flood impacts and durability with an unmodified hut with the aim of fulfilling objectives 2, 3, 4 and 5.

An exploratory study conducted with a community sample of 250 respondents is discussed, along with a detailed description of the methods used in the qualitative and quantitative stages of the thesis. The comparative case study design investigated differences and similarities in drivers and barriers to effective adaptation of the traditional African hut. Studies, such as Li *et al.* .(2017) have emphasized the substantial influence that comparative case study research can have on increasing understanding of CC adaptation. A practical approach was applied as a means to testing a theory of both adapted and old styled huts.

3.2 Rationale for choice of research methods

Qualitative and quantitative methods are viewed by many researchers as grounded in primarily incompatible philosophical paradigms (Gasper, 2006). Quantitative methods are generally associated with a 'positivist' paradigm; while qualitative methods are more typically grounded in a 'constructivist' epistemology. Nonetheless, while these links are often present, they do imply that qualitative and quantitative methods are essentially unequal (Bryman, 1988). Indeed, as Bryman (1988) showed, this distinction is misleading when we consider that the practise of natural science often does not conform to positivist ideas. The 'humanness' of scientific inquiry for example, into an approach whereby scientists rely on tacit knowledge and embody institutional values, is most clearly exposed in sociological studies of scientists (Collins, 1984; Golinski, 1998). Similarly, it is argued that there is no value-free account of CC; or indeed of any object of inquiry (Section 1.2.3). Conversely, the use of measurement in social research does not automatically indicate a commitment to positivism (Bryman, 2001). Silverman (2001) for example, argued that quantification (ideally, based on respondents' own categories) can give greater confidence in the accuracy of conclusions derived from qualitative data. *"Instead of taking the researcher's word for it, the reader has a chance to gain a sense of the flavour of the data as a whole"* (Silverman, 2001, p. 37). Thus, the distinction between particular qualitative and quantitative methods can be understood as primarily technical and not necessarily philosophical. Indeed, many social studies have successfully combined qualitative and quantitative methods of data collection and analysis.

3.3 Research approach

Research can be defined as a scientific and systematic search for relevant information on a precise topic and is capable of withstanding close examination (Kothari, 2004). Bryan (2012) added that research is aimed at gathering information to produce or to enhance knowledge. He pointed out that research usually has two approaches, the quantitative and/or qualitative approaches. In the case of CC adaptation, both approaches are used. Although the information that is needed for most of the research is qualitative, it is very complex. Thus, quantitative data are gathered via questionnaires and then analysed to obtain qualitative information. As the nature of a research topic, its aims and the resources accessible normally determine the design and strategy to be used for carrying out research. This research has considered these factors and chosen the best approach to simplify enormous amount of information (Brunner, 1986; Ibiebele, 1989).

Quantitative research strategy is supported by experimentation and usually attempts to compare one study with another, while qualitative research tends to depend more on case studies, in many cases using ethnography and grounded theory (Punch, 2005). He added that the selection of appropriate research strategy will depend on the nature of the research. In the course of this study, the qualitative and quantitative approach involving the buildings physical characterization and questionnaire survey were utilized to compare and analyse adapted and old styed traditional huts, to understand the type of obstacles and success factors of a well-adapted hut. It was decided that only one old styled hut in the same group as the demonstrated hut would be studied to give a detailed comparison.

3.3.1 *Research design*

The research location was Nigeria, to make the best use of time; it was designed to cover two visits to the study area. The first visit was to observe, survey and administer the pilot questionnaires. The research gathered data qualitatively by using procedures that embrace richness, depth, distinction, framework, multi-dimensionality and complexity (Manson, 2011).

The research was ultimately designed to collect information on the current state of traditional huts to attain insights into how to better adapt them to CC impacts. This information was collected via questionnaires, interviews and surveys to constitute compelling arguments on how these buildings work and why they have remained the way they are with little effort to adapt to CC. The first visit was a pilot visit to familiarize, observe and collect data via questionnaire and also build a modelled hut.

3.3.2 *Exploratory study*

An exploratory study was conducted using a sample of occupants in the case study community. The primary aim of the study was to investigate factors influencing and constraining environmental behaviour change, including environmental, social and experiential factors. The approaches used to collect and analyse data for this exploratory study are discussed.

Participants in the exploratory study were 250 respondents who had participated in hut building or owned a hut. This was to explore the diverse ways in which people in the community had responded to CC impacts or how they were preparing to adapt. It sought to explore people's attitude to the need to adapt to climate impacts.

3.3.3 *Ethical approval*

It was acknowledged that there are difficulties inherent in qualitative research and most were alleviated by obtaining approval for the questionnaire from an authorized ethical body of the University of Wolverhampton, with well-established ethical principles.

3.3.4 *Pilot survey*

Pilot studies are important to establish that a questionnaire is well designed and will be able to achieve all the data gathering objectives of the main survey. According to Gecchele *et al.* (2017) pilot studies can evaluate the clarity, feasibility and comprehensiveness of a survey, pilot studies can assist in testing the rigour and strength of methodological frameworks for surveys. To ensure validity of responses, it is often necessary to ensure that the sample for a pilot survey is selected from, or approximates to, the actual sample of the main survey (Susilo *et al.,* 2015). Five categories of variables that were expected to influence overall adaptation behaviours were identified and tested in the pilot survey. As a result of the distance from the case study area, time and cost constraints, the sample for the pilot survey and questionnaire were conducted on one visit. Questions where slightly revised to incorporate important issues observed/surveyed on-site before final administration.

3.4 Data collection method

An attempt to gather local government policies and strategies from the Benue State Environmental and Planning Department of the case study area (Makurdi) was made in fashion with exploratory theory. However, it was discovered that there were no active policies in place.

3.4.1 *Interviews*

Twenty in-depth interviews focusing on adaptation measures and planning policy were conducted with participants from the local community and suitable departments within the Makurdi Local Authority. The interviews were with 28 influential officials from the local government planning teams. Telephone interviews were planned to save costs, as participants considering reported advantages of increasing the participant's awareness of anonymity and also allow telephone calls allow them to express their views freely, undisturbed and easily (Greenfield *et al.,* 2000; McCoyd and Kerson, 2006). However, no telephone numbers or Email addresses were made available.

A semi-structured interview procedure was used (Brinkmann, 2013). This allows emphasis on the issues considered important for the research and ensured flexibility to the participants to discuss what they believed to be important. Interviews were conducted face-to-face and one-on-one with participants. The interviews lasted from 10-20 minutes, depending on the time the participant had available to talk.

3.4.2 *Survey questionnaires*

The study employed one questionnaire survey for all participants in collecting data on the barriers and success factors of adaptation of the traditional African hut in Makurdi, Nigeria. (Appendix 1 for a blank copy of the questionnaire, as designed by the author). The questionnaire was developed based on a comprehensive review of past relevant studies and ongoing issues in housing in the region. Questionnaires comprising primarily quantitative and a few qualitative questions were administered. These questionnaires were intended to measure the community's environmental attitudes, understanding and behaviour.

3.4.3 *Questionnaire design*

The entire questionnaire was divided into three sections: A, B and C. Section A contained personal background; Section B: House information Section; C: Building Material and maintenance. The bases that informed the choice of questions included:

The desire to obtain data that on analysis could help realize the immediate objectives of the research. To gather data in critical areas of adaptation in the City where presently there is none. Oppenheim (1992), De Vaus (2007) and Baker (2003) outlined the critical prerequisites of a good survey and recommended best practises for questionnaire design and administration. Following their recommendations, the questionnaires were designed for self-guided completion and worded to be brief, easy to be read, clear and unbiased.

The overall success of research is determined by the choice of questions (Kothari, 2004). He stressed that it is important to determine which questions need to be asked and what questions meet the research objectives and survey design. The research technique to be used may also require that certain types of question are asked (Fandle and Smith, 2013). In this research, questions such as Section C Question 3 "*What feature(s) did you renovate?*" are asked for the purpose of gathering data on most frequently repaired features of the hut, particularly enabling concentrating on improving and adapting these features.

3.4.4 *Sampling*

This research used a subjective sampling method in order to allow for specific cases that were seen as of particular interest in both adapted and old styled huts (Topp *et al.,* 2004). Cases were selected to address the research questions, ensuring that most adult age groups participated (Berg, 2001). The age groups covered young adults, middle aged adults and elderly to obtain historic, current and anticipated future data.

3.4.5 *Sample size*

The case study community is said to have population of ~1640 and the sample population aged ≥18 and is reported by the community head to be ~1214. Overall 900 questionnaires were distributed randomly to capture respondents, who were over 18 years, owned, built or maintained a hut. Some 300 questionnaires had respondents that matched the category that was sought. In all 314 (26%) out of 1214 people over 18 did not participate leaving the total number of participants as 74%. This meets the sample size measures suggested by Dworkin (2012). Some 250 respondents (85%) out of the 300 comprehensive questionnaires were selected based on respondents who filled in all the questions and agreed for their responses to be published anonymously, while 50 respondents who matched the category did not fill in all relevant information or denied any form of public opinion on their responses.

The research questions are asked to first match respondents to appropriate criteria for suitable respondents and to put them in the criteria that give the most probable analysis (e.g. age of respondents) to gather data on what the age classes thought about the traditional African hut. This was to obtain a historic interpretation of data. Another advantageous approach used in this research is face-to-face questioning and interviewing (Kothari, 2004). It gives the opportunity to show respondents exactly what the hut looked like and to remind them of each aspect by just glancing at the picture (Appendix 8.2).

3.4.6 *Data triangulation through focus group discussions*

Questionnaires and interview analysis on the present state of adapting the *Tiv* traditional hut provided critical requirements for the proper understanding of present methods. The purpose of the focus group discussion was to reinforce and verify data and results from previous methods. Participants in the group discussion were randomly drawn from respondents who indicated interest to be contacted for further discussion. The main factors considered while selecting participants were:

1. Participation in the questionnaire survey.
2. Knowledge of the subject based on the answers on the questionnaire.
3. Owner of a hut.
4. The process for recruitment of participants involved a telephone request to participate and confirmation of attendance.

5. Number of invitations sent to participants was 280, with 200 participants present for the discussion, 50 at each of the four meetings.

3.4.6.1 Focus group design

The objectives of the Focus group discussion were:

a) To provide a platform for stakeholders to discuss the barriers and success factors affecting CC adaptation of the *Tiv* hut.
b) To strengthen evidence and findings from the questionnaire survey and desktop findings.
c) To prescribe policy options for achieving workable adaptation strategies in Benue State.

A controlled, but relaxed, atmosphere was ensured to encourage participants to talk easily on the topic. General, but engaging, questions such as most popular foods and drinks were served as ice-breakers. Two key questions were asked on the method and style of the current hut. Responses were recorded by audio and transcribed for analysis using coding. The overall position of the entire focus group on current methods of adapting the traditional hut for CC impacts was analysed using coding. This was done with a view to prioritizing and recommending strategies and policy options for adapting best practises that suit local environments. Multi-criteria analysis was carried out to gather data on what is most important to stakeholders and design adaptation strategies in order of importance.

3.5 Multi-criteria analysis

The study explored the potential of Multi-Criteria Analysis as a technique for climate adaptation assessment in order to prioritize the adaptation measures to be undertaken. Adaptation assessment is piloted within the framework of the Multi-Criteria Analysis technique, which allows both normative decisions and practical expertise in the assessment process.

Developing countries suffer the most in respect to CC inconsistency, as they lack basic infrastructure to protect their cities. In addition, the means and technical expertise are limited. For this reason, the adaptation methods to protect their cities have to be well planned and prioritized sensibly to reduce vulnerability. A structure for prioritization of adaptation measures is lacking in the decision making in this context, which could greatly help in informed and structured decisions through the planning process of adaptation strategies in developing countries (Haque, 2016). He pointed out that participatory integrated assessment of adaptation options is a new approach in disaster management in less developed countries. The assessment framework has been applied and tested at the eastern fringe of Dhaka City, which is very vulnerable to flooding. Based on the assessment and analysis, adaptive measures were prioritized to enable more effective action. The seven steps of Multi-Criteria Analysis suggested by IPCC (2014) are used in Chapter 4.

3.6 Research considerations

3.6.1 *Trustworthiness of data*

It is acknowledged that limitations of trustworthiness are inevitable. Suggestive measures are used to contest these limitations throughout the data collection and analysis process to minimize the limitations. A comprehensive reporting system has been employed in the collection and analysis of the research data, as this is key to justifying and assuring that trustworthiness exists in the study (Henderson, 2006 in Veal, 2011). All four components of trustworthiness (credibility, transferability, dependability and conformability) were employed (Veal, 2011; Bryman, 2012; Loh, 2013). The combination of these four terms constitute the trustworthiness criteria, thus forming the conventional pillars for qualitative methodology (Goodson and Phillimore, 2004).

In the case of **Credibility**: the validity of the findings is tested using the model to measure and compare climate impacts (such as temperature, rainfall, flooding and lighting) over a two-year period, as the maximum time available in the duration of this research. Related strategies used by other researchers to format more suitable methods of collecting and investigating were cross-checked (Shenton, 2004; Porter, 2007). On **Transferability**: step-by-step procedures on the method of building an adapted traditional building are listed and explained in detail to allow applicability of the findings in other contexts.

Dependability: As there is detailed description and a physical structure to make reference, the research is reliable in terms of the findings at another time, as long as the prototype hut proves its purpose and benefit over the existing unmodified hut. Dependability is usually complex and sometimes hard to prove, especially in research with a short time to monitor. In the case of CC, hoping that current data are still dependable may be problematic. Efforts were made to reduce mistrust by giving detailed and reasonable information on the processes and reasons why they should be trusted (Riviera, 2011; Bryman, 2012). If the same procedure carried out in this research is repeated with the same participants, the results are highly likely to produce the same outcomes.

Conformability: samples were randomly selected to remain objective, which increases conformity (Ryan, 2015; Shenton, 2004). Research steps and outcomes were matched against objectives. A second field visit was carried out for interviews and a question added to verify that information given in the first visit has been used in the design of the prototype hut.

3.6.2 *Language barriers*

Most respondents of the research case study do not speak English; an English graduate who speaks '*Tiv*' was willing to help correctly interpret the exact meaning of concerned participants who did not speak English. This adds to the trustworthiness of the research, reducing misinterpretation and limitations.

The research confirms the hypothesis that there are cost benefits associated with adapting to CC in the area (Bryman, 2012). The research interval gave it ample time to ensure that the study measures and tests matched what is actually intended (Ryan, 2015; Shenton, 2004; Porter, 2007).

3.7 Data analysis

As one of the key proponents of the exploratory theory approach, analysis was undertaken throughout the data collection stage (Bryman, 2012). No documents were found on the local authority website on policy and strategies on either CC or adaptation. Interviews were conducted with 20 officials in the departments responsible for housing those affected by CC impacts, who also lived in the community. Interviews were transcribed by hand immediately after the interview, which meant that analysis occurred almost immediately. After transcription, the data were scrutinized and sorted (Cloke *et al.,* 2004). Coding was used to highlight certain words and phrases for further analysis and subsequently commonly occurring themes were identified and important parallels and contrasts were noted (Jackson, 2001). The Multi-criteria Analysis method was used to prioritize adaptation options.

3.8 Role of the researcher

3.8.1 *Beneficence*

The research questionnaire had a brief introduction respecting respondents' the right to consent or not answer. It also clearly stated that respondents could at any point stop answering and do so anonymously, if they so choose. The same applied to interviews, with questions asked openly for participants to give information they were comfortable with, which means making a reasonable balance between over-informing and under-informing (Kvale, 1996). It also means that participants exercise their rights as autonomous persons to voluntarily accept or refuse to participate in the study (Kvale, 1996).

3.8.2 *Transparency*

The problem of adapting to CC was considered among all adult age groups and focused historic data collection on elderly men and women, who have detailed knowledge of the cultural heritage of the *Tiv* vernacular building. This was to give them the opportunity to decide for themselves and for their experiences to be heard. Very old people who had issues with consenting were not interviewed (Smith, 1999). Participants were treated anonymously. The respondents were told how results would be published. Participants were informed on the use of their quotations for analysis in publications and were given the opportunity to consent.

3.8.3 *Justice*

The exploitation of victims was avoided. Listening to the voices of minority and disadvantaged groups who live in far worse shelters than the unmodified hut was important (Capron, 1989). Practical problems arise when researchers try to implement the principle of justice. For instance, the implementation of the principle of justice should not further burden the already burdened vulnerable groups of participants. An example was the situation in which the consent forms for a group of Ethiopians for a rabies vaccine trial were not translated into the local language.

3.8.4 *Implications for researchers*

In the interviews, participants were listened to without interference. It was recognized that being from the research location and having prior knowledge of it may raise several issues and ethical considerations. It was therefore important to carry out the research on very neutral grounds by avoiding assumptions and untested conclusions. The research is undertaken in a community where the researcher is not known, so as to get the most information possible. Conducting research in one's work area creates problems related to the validity, reliability and meaningfulness of the data. Conducting research in another setting may mean that researchers must spend more time and effort establishing rapport and learning the new setting (Field and Morse, 1992). But, this change may result in more objective observations. Negotiation of the researcher's role in a case study area is important. The role was clearly identified by the group and the purposes of the study were discussed to avoid suspicions and false expectations.

3.9 Limitations of the research

3.9.1 *Time limitations*

1. The time-frame of four years does not give sufficient time to conclusively state that the life span of the adapted hut will be as long as assumed.

2. Monitoring the building maintenance cycle based on three years may be unrealistic.

3. A particular problem could go unnoticed, as it has no set criteria to match against (Bowen, 2009). Furthermore, the interpretations of researchers are limited. Further limitations are discussed in Chapter 6.

3.9.2 *Verification of results*

Because of the open-ended nature of interview questions in this research, participants had more control over the nature of collected data. There was no standard to compare and match responses against.

3.9.3 *Labour-intensive approach*

The qualitative study requires a labour-intensive analysis process, such as categorization and recoding (Elo and Kyngas, 2008). Similarly, qualitative research requires well-experienced researchers to obtain data from the respondents. Different conclusions are derived based on the same information, depending on the personal characteristics of the researcher (Maxwell, 2005).

3.9.4 *Difficult to investigate*

Researchers find it difficult to investigate causality between different research phenomena. Qualitative research is complex to explain (Barbour, 2000). For example, to determine if human development depends on the level of education, interview or focus group data were collected from the residents of Uttar Pradesh. It is difficult to determine the effect, owing to varied perspectives, which are difficult to gauge. This is due to the lack of statistical results, which would have made the procedure more systematic. Qualitative study requires thoughtful planning to ensure the obtained results are representative. Qualitative data are not amendable to mathematical manipulation. This type of research is based more on opinion and judgment, rather than results. All the qualitative studies are unique and difficult to replicate.

3.10 Procedures

All information was collected directly from the head of household of any adult aged 18 years and older with sufficient knowledge of the household. Data were collected using a questionnaire covering six modules: 1: Demographics, household characteristics and socio-economic census, 2: Hut history, 3: Household environment, 4: Renovation/repair details, 5: Cost of repair and 6: Main areas of concerns .The following explains the reasons for the choices that were made in respect of material, design, cost and environment.

3.11 General building design consideration for the tropics

The tropics have an uncomfortable climate, as it receives an enormous quantity of solar heat. (Al-Obaidi *et al.,* 2014). This leads to high temperatures and humidity levels as accompanied with long periods of sunny days through the year. Chávez *et al.* (2016) reported that in 2013, Solar GIS presented a world map of global horizontal irradiation. This map shows the zones receiving ≥7 kW-h m^2 corresponds to those of lower latitude. Africa is one of the three zones most exposed. South Asia and Latin America are the other two zones. The hottest zones present annual mean temperatures between 31-35°C. Nigeria fits this description (Saikkonen *et al.,* 2012). One of the key aspects in need of adaptation in the region is cool interior houses adapted to high outside temperatures.

Every aspect of the unmodified building's structure of the hut is examined in order to develop and embrace an integrated method for sustainable construction. This is exemplified in the work by Worth *et al.* (2007). They compared choosing concrete tiles over lightweight steel sheeting, which needs larger supporting members and therefore greater material quantities and transportation requirements. They stated that such a choice of one type of roof construction above another might have substantial effects on the environmental impact of a construction. Worth *et al.* (2007) concluded that the choice of materials is based on the cost of purchase and installation of a particular option. They added that given the competitive nature of the building industry, cost is likely to remain the determining reason in the choice of materials and construction methods. One of the considerations of building in rural Nigeria and especially Benue State is the availability of raw materials.

3.12 Building of an adapted hut

The approach was carried out in fulfillment of Research objectives 2, 3, 6, 7 and 8. It was illustrated by a detailed literature study to identify common climate-related issues with traditional African huts especially of the Tiv people of north-central Nigeria, called '*Ate*' or '*iyough Toho*' directly translated as the 'house of grass'.

3.12.1 *Building plan*

A plan of the model showing a floor plan, section approach and rear view (Figures 3.1-3.4,) designed to withstand identified issues from the questionnaire, survey and interviews. The original size on the plan was changed as it was too large compared to on-site examples. Some of the features adapted are:

- Flooding.
- Low Lighting.
- Temperature.
- Rainfall.

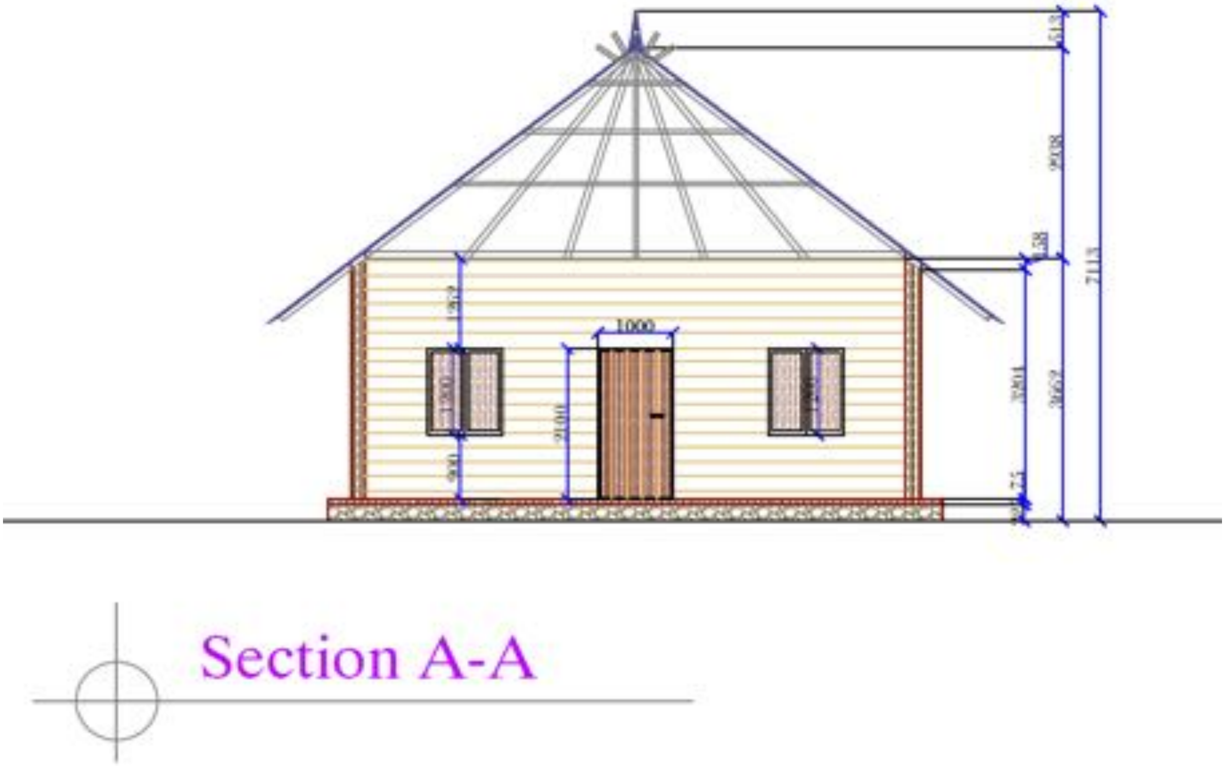


Figure 3.1. Cross section of the building plan (prototype, with measurements in mm).

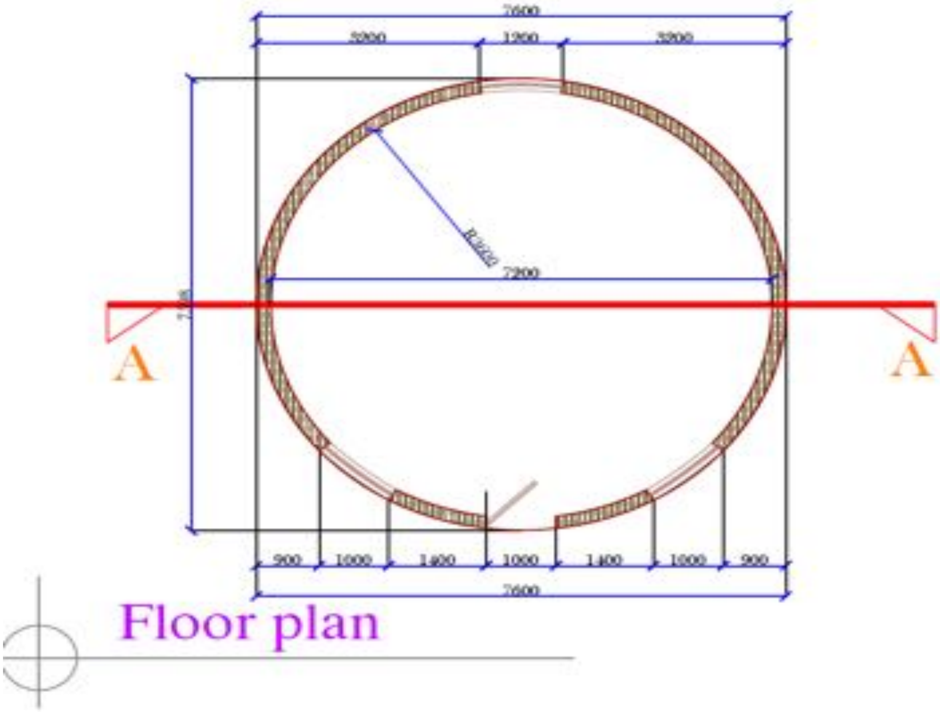


Figure 3.2. Floor plan of building plan (prototype).

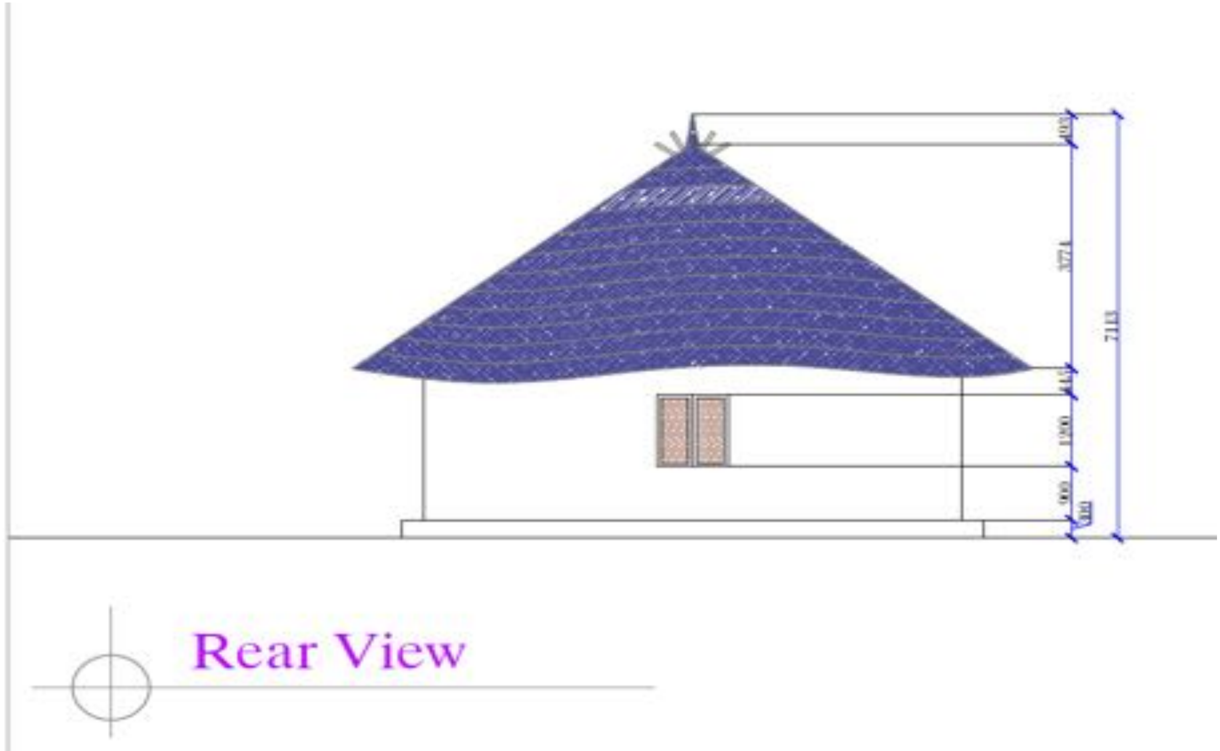


Figure 3.3. Rear view of the building plan (prototype).

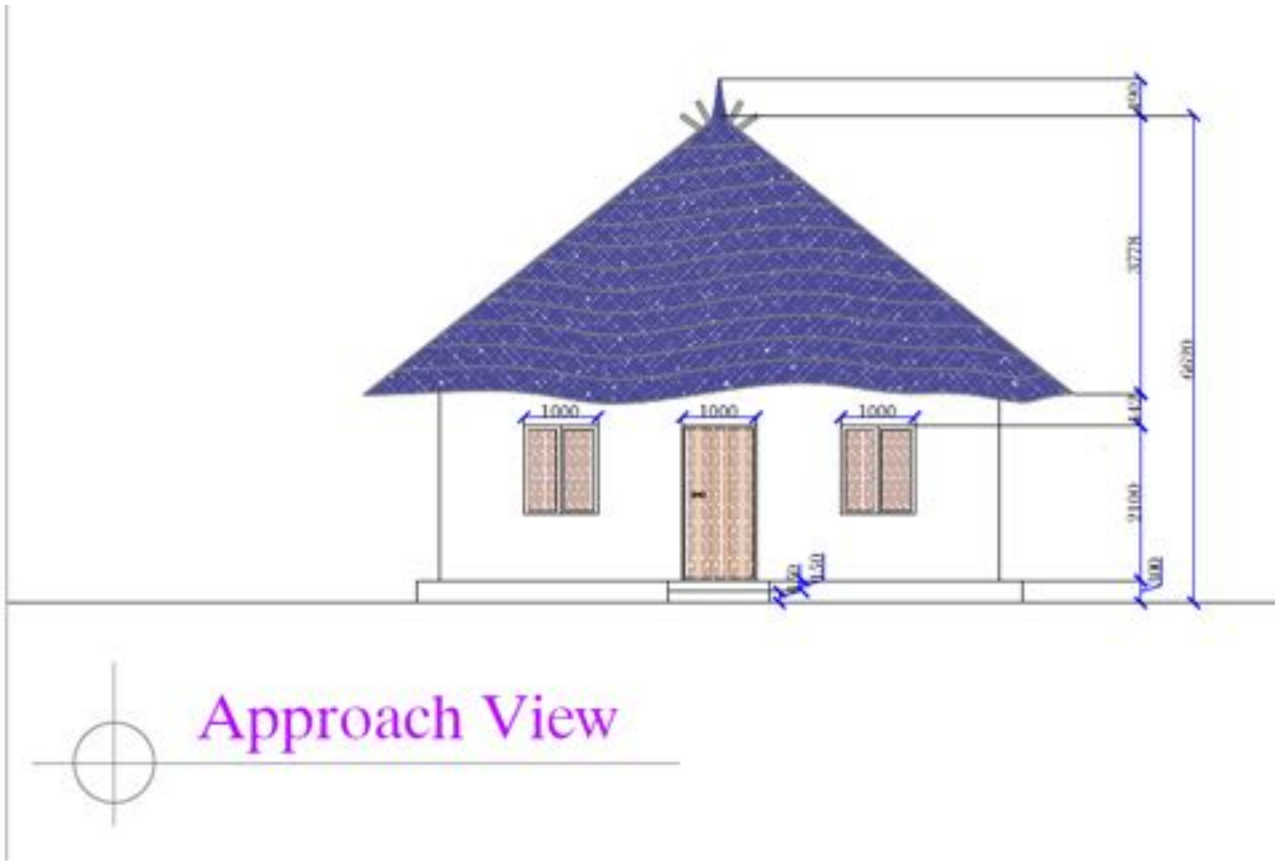


Figure 3.4. Approach View of building plan (prototype, with measurements in mm).

3.13 Material sourcing

An important aspect of building a shelter with the intention of reducing extreme climatic impact is to consider building materials and their life span.

3.13.1 *Life-Cycle Design*

A recent 'cradle-to-grave' analysis of building products emphasized life cycle cost of a building starting from the gathering of raw materials to their eventual disposal, providing an understanding of the long-term costs of resource (Udawattha and Halwatura, 2017). They argued that the principles of life-cycle design provide important guidelines for the selection of building materials. This has helped the choice of materials with the longest life-span. Based on the results of Udawattha and Halwatura (2017), each step of the manufacturing process, from collecting raw materials, manufacturing and fitting, to eventual reuse was examined in this investigation for its environmental impact. These three life-cycle phases relate to the flow of materials through the life of the building (Figure 3.5).

3.13.2 *Building phases*

All three phases (Pre-Building; Building; and Post-Building) are parallel to the life-cycle phases of the building itself. The evaluation of building materials' environmental impact at each stage allows for a cost-benefit analysis over the lifetime of a building, rather than simply an accounting of initial construction costs (Figure 3.5).

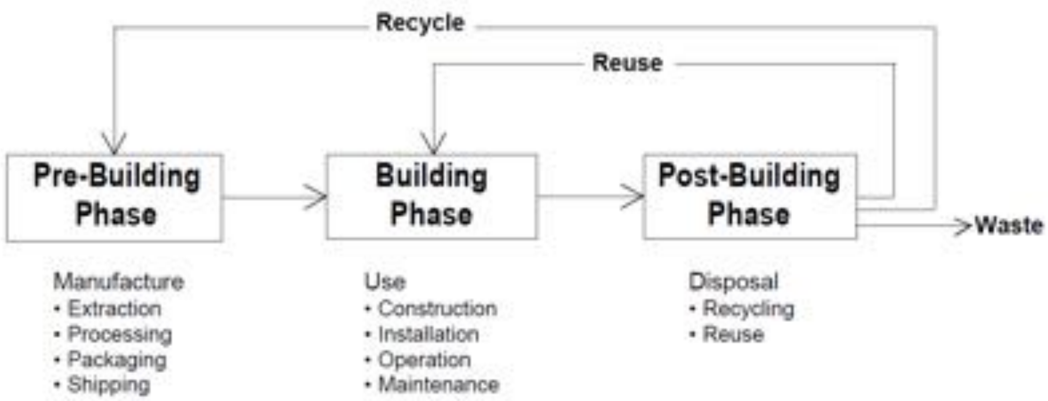


Figure 3.5. Material's life cycle (source: Udawattha and Halwatura, 2017).

3.13.3 *Reducing building energy consumption*

To reduce the environmental burden of the construction sector, reducing building energy consumption during the operating period has most impact on a building life-cycle (Cabeza *et al.,* 2014; Arigoni *et al.,* 2017). The reduction of operational energy is achieved by substantially increasing the amount of insulating materials (Ruggieri *et al.,* 2013). The amount of energy embodied into buildings is rapidly increasing (Crawford *et al.,* 2016), partially nullifying the benefits coming from improved thermal efficiency (Melia *et al.,* 2014). To counterbalance this effect, selected building materials were selected with low embodied energy. Natural materials are perfect candidates, because they normally go through few industrial manufacturing operations, so accumulate little embodied energy (Melia *et al.,* 2014). A comparable approach is valid for CC mitigation (Nordby and Shea, 2013). A viable route to help achieve the mission of emission reduction is the selection of low embodied carbon (C) building materials, possibly characterized by high C storage, such as wood used in the construction of the prototype (Lawrence, 2015). Some of the material choices are shown in Figure 3.6.

Stage 1. Site location

3.13.4 *Identification of flood prone zones*

The study examined strategies in place to minimize flood disasters in the case study area. However, there was little literature mapping the flood zones. A study by Clement (2013) attempted to map out zones as shown in Figure 3.7, showing a map of residential buildings close to a major river and are therefore prone to flood impacts. The purpose of such information is to guide the public on choosing an appropriate and safe site for residential structures. The site was chosen where there is natural shading by vegetation and a southern-facing axis. Stage 1 describes each aspect of the foundation and methods, with explanations and motives.

Figure 3.6. Building materials used, (source: author's photograph, 2015).

Figure 3.7. Flood zones/real scenario Makurdi, Benue State, (source: Clement, 2013).

3.13.5 *Foundation construction*

After choosing a site, the prospective hut owner obtains permission from the local headsman (community chief) to build. In this case, land was given for the project at no cost by the land owner and permission was given by the village chief. Using a string tied to a peg, a circle of the desired hut radius was marked out. In this case, 5.8 cm was measured and marked. The circle was drawn using a long nail tied to the 5.8 mm rope to form a diameter of 11.6 mm (Figure 3.8). To maintain the diameter of the internal floor space, a 5 cm gap from the measurement is taken outward with the peg still in place and measured round to give a 12.2 cm total diameter (Figure 3.6).

Figure 3.7. Measurements for foundation, (source: author’s photograph, 2015).

Figure 3.8. Digging of foundation, (source: author's photograph, 2015).

An approximate depth of 5 cm was dug and filled with a concrete cement mixture (Figure 3.9). Burnt bricks measuring 5 x 6 cm were placed with a 2 cm gap and filled with concrete-cement mixture (Figure 3.10).

Figure 3.9. Construction of concrete base foundation, (source: author's photograph, 2015).

The technique above was repeated on three rows to complete a concrete base foundation measuring 300 mm and left to cure for 3 days (Figure 3.11). Because Benue is a flood-prone region and even though flooding is currently of low severity in this location, the foundation was raised above ground level to minimize damage in the event of increased future occurrence.

Figure 3.10. Concrete foundation wall, (source: author's photograph, 2015).

Figure 3.11. Storage of blocks, (source: author's photograph, 2015).

Materials that can get wet and then dry out with minimal damage are used for the entire building, with the foundation reinforced with concrete and aggregates to increase water resistance. Materials consist of burnt bricks, concrete mixture of cement, sharp sand and stones, which are locally available and considered environmentally-friendly. This foundation minimizes floodwaters from passing under the house or allows them to pass without destroying it.

3.13.6 *Volume stability and crack control*

Specialized flood barriers, such as those made by Savannah Trims, show that even homes elevated satisfactorily to meet minimum National Flood Insurance Program (NFIP) criteria can experience flooding above the base-flood. Many communities require that homes be elevated above the Base Flood Elevation (Federal Emergency Management Agency (FEMA), 2013) (Figures 3.13, 3.14).

The concrete mixture used for binding dried clay was left to cure to reduce creeping (deformation per unit of time) as the rate of creep decreases with time. Hardened concrete changes volume due to changes in temperature, moisture and stress. These volume or length changes may range from ~0.01-0.08% (Kosmatka *et al.,* 2003). Thermal volume changes of hardened concrete are about the same as those for steel, making a concrete foundation one of the most durable. Water quantity used in the mixture depends on the components. The model built in this research used Mix 2 to allow for shrinkage and expansion (Figures 3.15, 3.17). Since concrete kept continually moist will expand slightly, when permitted to dry, concrete will shrink. In building the model, it was noted that the primary factor influencing the amount of drying shrinkage is the water content and the shrinkage increase is directly proportional to increased water in the mixture.

FEMA (2014) suggested that to successfully elevate a home on an open foundation, site-specific environments must be recognized. Once the site-specific conditions are identified and appraised; a suitable design can then be implemented. Some of the site-specific factors to be considered include soil conditions; the required elevation; and flood, wind and seismic loads (FEMA, 2014). To achieve successful adaptation in the case study, a survey of similar structures was carried out and the questionnaire aims to obtain information on floods, temperatures, lighting and rain.

An existing hut in the area, only 12 houses away from the site of the prototype, was chosen for comparison. The hut was surveyed and critically observed and the dwellers were given questionnaires to complete. Although there were no data on any of the parameters set to be measured (temperature, rainfall/flood and humidity), the life-cycle of the building yields useful information. A room thermometer was fixed to take daily temperatures in both the existing and the prototype huts to compare their thermal regimes.

Questionnaire distribution was aimed to cover homeowners, builders and design professionals who need to know the flood risk for the location of the home in order to determine how high the prototype must be elevated. Most flooding occurs from either riverine or ocean sources (FEMA, 2014). The case study area has one of the largest rivers in Nigeria and usually overflows during peak rain periods.

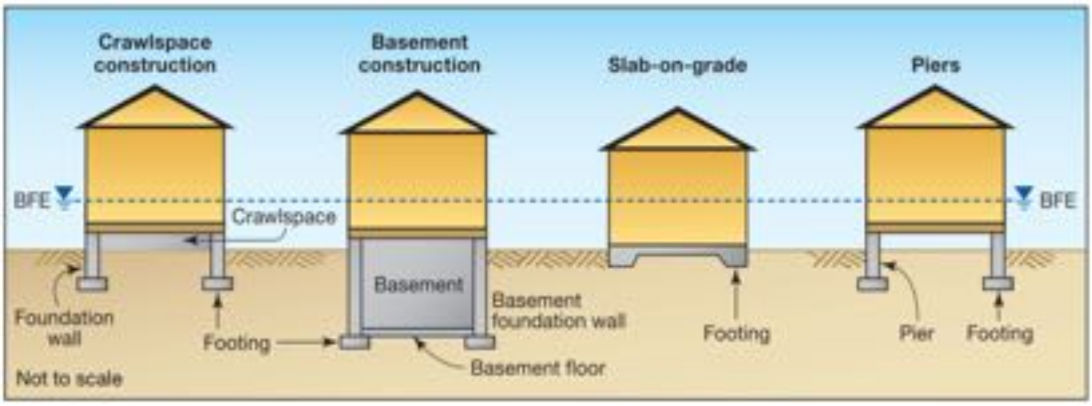


Figure 3.12. Flood zones and foundation type, (source: FEMA, 2013).

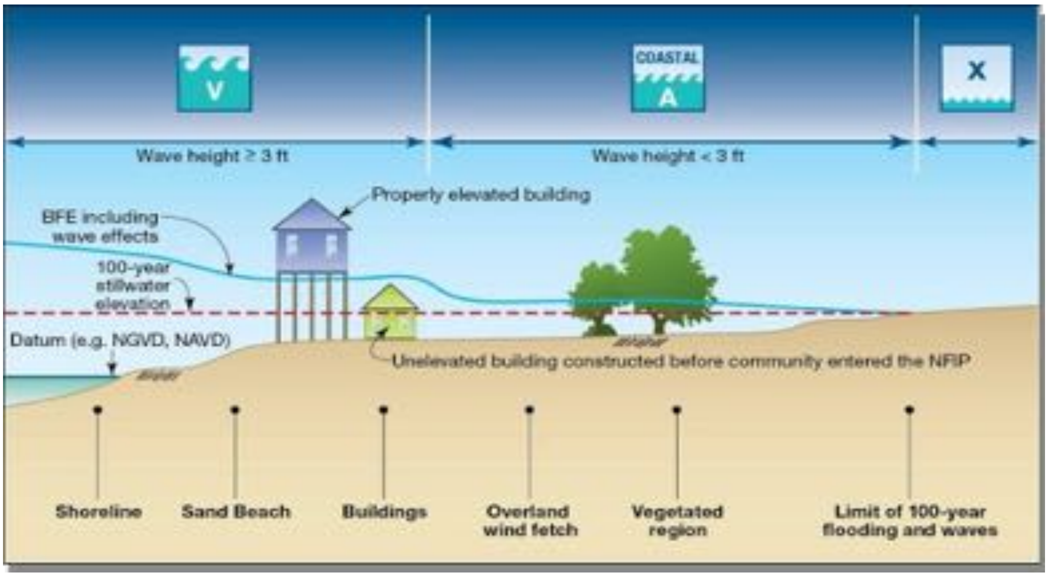


Figure 3.13. Building elevation base on water levels, (source*:* FEMA, 2013).

Success cases in underdeveloped countries, such as Chile and in developed countries such as the USA and UK that have detailed procedures for minimizing flood hazards were studied. For example, FEMA gives step-by-step guidance in identifying flood risk and determining whether a home is located within a Special Flood Hazard Area (SFHA) and what Base Flood Elevation (BFE) applies. Meanwhile, in developed countries the relevant studies were reviewed and taken to local floodplain building officials to confirm the location of the home using information from relevant authorities. The case is different in developing countries, such as Nigeria, as such the structure and approach are lacking in many regions, including Benue State. They added that such information is usually on the source and type of flooding risks that could potentially affect the property, such as the flow velocity, wave action, debris impact and depth of flooding. There are necessary to determine the type of foundation needed and other requirements (Figure 3.13).

3.14 Stage 2: Wall, door and window

3.14.1 *Walls*

Walls have two main impacts on building sustainability. Firstly, they are the biggest component of a building for covering and generally have the most environmentally impact. Secondly, most heat lost in a house is through the walls. The materials, their embodied energy and transportation requirements are very important to the sustainability of the overall building.

Breathable walls are also very important as they help to stabilize the humidity of internal air. This can improve air quality for people who suffer from breathing-related issues and reduce the number of bacteria and fungi that thrive on variable air humidity. Kubba (2017) investigated sustainable building methods using BREEAM standards and suggested that when building breathable structures, it is important that the internal walls be more resistant to water vapour than the outer ones. This means that water is constantly being drawn away from the interior. When using lime, a good way of achieving this is to use hydraulic lime internal plasters and lime putty external renders. Surface of earth walls is easily eroded and therefore regular maintenance is required (Lyamuya and Alam, 2013).

3.15 Building stage

3.15.1 *Considerations for building walls*

3.15.1.1 Water absorption

To get a good mix of the wall material, existing literature on the subject was studied. Water absorption of clay bricks without additives varies from ~8-21%, mainly due to slight differences in raw materials and manufacturing process (Ahmad *et al.*, 2017). They noted that additives of >15% were over the acceptable limit (20%) of water absorption and water absorption was closely related to porosity. Block sizes used for the construction were increased from 4.5-6 cm in thickness to stop water intrusion and increase time for heat to travel. A test conducted on-site proved that clay blocks used for the controlled hut increased from 3.4 kg to 4.0 kg when kept immersed in water for 24 hours (Kosmatka *et al.*, 2003). The current of blocks made from mud increased in size from 2.5 kg to 4.4 kg. A graph of one of the material mixtures shows in water absorption the clay bricks with additives and fired at 1000◦C resulted in 14–35% absorption for coal addition and 16–37% for wheat husk addition (Figure 3.15). Results proved that the more the additives, the less water resistant the blocks become.

3.15.2 *Permeability and water tightness*

Concrete used in water-retaining structures or exposed to weather or other severe exposure conditions must be virtually impermeable (Kosmatka *et al.*, 2003). Water tightness is often referred to as the ability of concrete to hold back or retain water without visible leakage. Permeability refers to the amount of water migration through a surface or to the ability of concrete to resist penetration by water or other substances (liquid, gas or ions). Generally, the same properties of concrete that make it less permeable also make it more watertight. A simple test of dipping the blocks currently used by residents and one used by the model reveals that the latter has 24-hour resistance to water, while the other had only 8 hours before disintegrating (Figure 3.16).

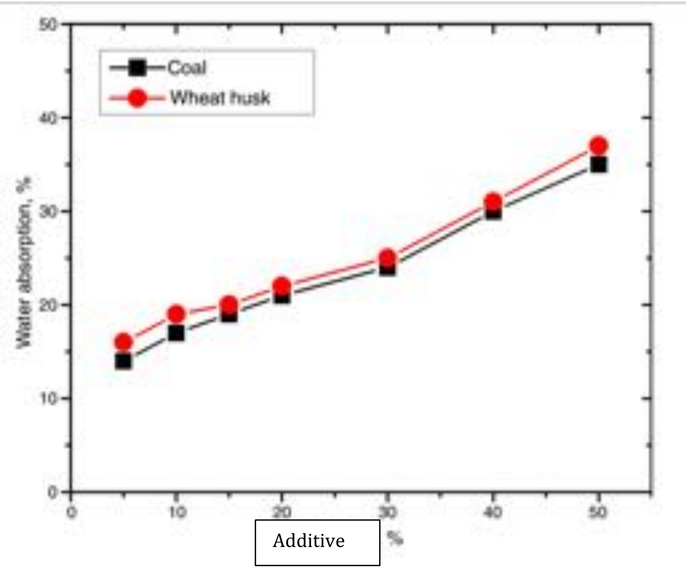


Figure 3:14. Effect of admixtures on the water absorption of the samples, (source: Kosmatka *et al.* 2003).

Figure 3.16. Test on water absorption of blocks, (source: author's photograph, 2015).

3.15.2.1 Abrasion resistance

Floors, pavements and hydraulic structures are subjected to abrasion; therefore, concrete must have high resistance to abrasion. Test results indicate that abrasion resistance is closely related to the compressive strength of concrete. Strong concrete has more resistance to abrasion than weak concrete. Since compressive strength depends on the water-cement ratio and curing, a low water-cement ratio and adequate curing are necessary for abrasion resistance. The type of aggregate and surface finish or treatment used also strongly influences abrasion resistance. Hard aggregate is more wear-resistant than soft aggregate and a steel-troweled surface resists abrasion better than a surface that has not been troweled. Concrete is basically a mixture of two components: aggregates and paste. The paste, comprised of Portland cement and water, binds the aggregates (usually sand and gravel or crushed stone).

Since aggregates constitute 60-75% of the total volume of concrete, their selection is important. This is why aggregates consisting of particles with adequate strength and resistance to exposure conditions are used, avoiding materials that will cause deterioration of the concrete. Consolidation of coarse and stiff mixtures is used to improve quality and economy. On the other hand, poor consolidation can result in porous, weak concrete with poor durability (Figure 3.17).

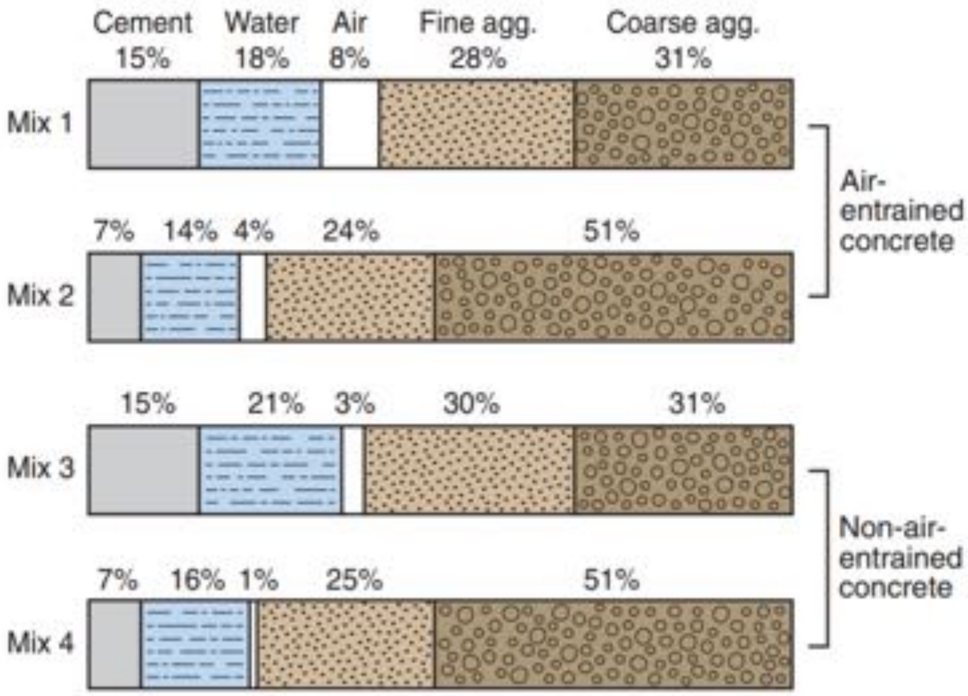


Figure 3.17. Material mixtures, (source: Kosmatka *et al.,* 2003).

The larger the size of aggregate, the more paste it requires. With a well-graded aggregate, the less volume there is to fill with paste and the less aggregate surface area there is to coat with paste; thus, less water and cement are needed. Concrete with an optimally graded aggregate as use in the model is easier to consolidate and place.

Figure 3.18 shows the clay used for building the hut and Figure 3.19 shows smooth blocks covered with light grass to stop cracking due to aggressive desiccation by the sun. The door is measured by obtaining the radius measuring outward 400 mm both sides (Figure 3.20). The procedure is repeated throughout the wall building phase, to avoid building into the opening.

Figure 3:18. Clay soil mixed with water, (source: author's photograph, 2015).

Figure 3.19. Brick layer box coated with plastic vinyl carpet to improve smoothness, (source: author's photograph, 2015).

Figure 3.20. Door position marked, (source: author's photograph, 2015).

3.16 Justification for materials used

3.16.1 *Non-fired bricks*

Bricks can be made and left to dry naturally. They only use 14% of the energy used to make normal bricks (Kubba, 2017). Non-fired bricks are normally used for internal non-load bearing walls. They are breathable, light and provide good thermal insulation. Non-fired bricks used in this study were air and sun-dried. To prevent harsh drying, which results in cracking when used, some weeds were used to cover the bricks and avoid direct harsh sun-light to allow slow air drying. Using cement rather than lime mortar makes recycling stone and brick much more difficult and uneconomic. For this reason, cow dung, which is also recyclable, is mixed with clay for plastering the interior wall.

The surface of an earth wall is easily eroded and therefore regular maintenance is required, at least once a year (Lyamuya and Alam, 2013). They suggested a more lasting maintenance-free wall can be obtained by plastering with a cement mixture. However, this study used an environmentally-friendly approach by pitching the roof at 45^0 and extending the overhang to minimize erosion of the wall due to excessive water splashing. Secondly, clay used will usually soak in much water without washing off, thus minimizing repair costs.

The energy consumption of the affordable housing industry plays a vital role in environmental sustainability, waste generation and energy consumption. The development of sustainable housing construction methodology helps with economic and sustainable development. The wall and roof are the most significant building components in a dwelling unit. Therefore, careful and well considered materials and methods were used.

3.17 Life cycle cost (LCC)

Life cycle cost (LCC) is a combination of all the costs incurred from construction to the end use of the building. The LCC comes from three different stages in the building using process; initial cost, maintenance cost and replacement cost. The reusable material cost was deducted from the total cost and the total LCC of the building was calculated. Perhaps most of these building materials are recyclable and reusable for other use. However, considering calculation the recycle cost and resale cost of different usages are usually omitted in calculations (Amadi *et al.,* 2012).

3.17.1 *Avoiding building failures to save cost*

In Nigeria, building failure has been attributed to causes such as design faults (50%), faults on construction site (40%) and product failure (10%) (Ayininuola and Olalusi, 2004). Faulty design, faulty execution of work and use of faulty materials are major causes of building collapse (Hall, 1984). The causes were physical factors, environmental status of the site, composition of technical components, social factors, economic factors, engineering factors, human factors, government policies and political factors (Fordham, 2000). Those who investigate and report on failures of engineering facilities are in a good position to identify trends leading to structural safety problems and to suggest topics for research to mitigate this trend (Ibrahim, 2013). Taiwo *et al.* (2002) listed environmental changes, natural and man-made hazards, improper presentation and interpretation in the design as major causes of building collapse.

3.18 Stage 3: Windows

For best ventilation, the building was designed with controllable natural ventilation (Fordham, 2000). A very high range of natural ventilation rates is necessary so that heat transfer between inside and outside can be selected to optimize conditions. Ventilation rates are selected to control temperature, pollution and air movement. Ventilation with heat reclaim and the thermal capacity of the building are considered. The prototype was designed with natural ventilation to minimize the use of fossil fuel energy.

3.18.1 *Design cooling-load-avoidance measures into buildings*

The building geometries are used to limit solar gain on east and west façades, (Figure 3.21), limit the area of east- and west-facing glazing, incorporate exterior shading devices above glazing and specify glazing tuned to the orientation. High insulation levels are incorporated to reduce conductive heat gain and provide optimized day-lighting to minimize the use of lighting. Taiwo *et al.* (2002) listed the following as major causes of building collapse environmental changes, natural and man-made hazards, and improper presentation and interpretation of the design.

Figure 3.21. Measuring of wall height to mark window height and positions (source: author's photograph, 2015).

Figure 3.23. Fitting of door and measuring of wall height to mark window height and positions, (source: author's photograph, 2015).

Figure 3.24. Fitting of window (source: author's photograph, 2015).

3.18.2 *Designing natural ventilation in buildings*

In some environments, predominantly those with low relative humidity, buildings can be designed to depend entirely on natural ventilation. In more humid climates, natural ventilation could be more applicable as a backup cooling plan that can be used during power outages as an inactive measure.

Figure 3.25. Laying blocks to close window to position, (source: author's photograph, 2015).

Figure 3.26. Completed wall showing raised door level, (source: author's photograph, 2015).

Stage 4: Roofing

In numerous buildings, the roof is a main element that provides the building with its unique shape. The aspects of a roof, which may contribute to the special interest of a protected structure, include the profile and structure of the roof, the material used for covering and other details associated with the roof (Worth *et al.,* 2007; Chávez *et al.,* 2016). The thatched conical shape of roof is common in the study area and for preservation of cultural heritage and appearance it has been preserved in this work. A step-by-step procedure of roof construction is demonstrated in Figures 3.27-3.33.

Figure 3.27 Construction of roof structure, (source: author's photograph, 2015).

3.18.3 *Conical-shaped roof*

The conical roof is a three-dimensional structure, which is particularly used in rural areas. It is easy to assemble and can be built with locally available materials, making it inexpensive. It must be constructed with an appropriate slope (35-45^0) for the roofing materials used to prevent it from leaking (Food and Agriculture Organization, 2014). The conical roof design is limited to rather short lengths and to circular or small square buildings.

Figure 3.28. Measuring distance between roof beams, (source: author's photograph, 2015).

The spacing of the purlins which support the roofing depends on the size and rigidity of the roofing material. The dimensions of the purlins depend on the spacing of the rafters and purling, the weight of the roofing material and the loading on the roof from wind and persons constructing and maintaining the roof (FAO, 2014). Bamboo was used for purlins, since roofing material can be easily attached by tying it with binding wires. Since the spacing of trusses is 2.5-3 m, bamboo purlins are particularly appropriate (FAO, 2014). Once the roof structure was complete, the roof framework was lifted onto the walls by a group of community helpers and the supporting poles were put in place, where necessary. If the owner wishes to remove the hut to a different site, the reverse procedure occurs. Both processes are treated as social occasions and beer and palm wine are supplied to people giving assistance.

Figure 3.29. Adjustment and lighting of beams, (source: author's photograph, 2015).

Figure 3.30. Capping and laying of thatch, (source: author's photograph, 2015).

A conical-shaped roof structure requires rafters and purling and in circular buildings, a wall plate in the form of a ring beam (Figure 3.31). The ring beam has three functions:

- ✓ To distribute the load from the roof evenly to the wall.
- ✓ To supply a fixing point for the rafters.
- ✓ To resist the tendency of the inclined rafters to press the walls outward radially by developing tensile stress in the ring beam.

If the ring beam is properly designed to resist these forces and secondary ring beams are installed closer to the centre, a conical roof can be used on fairly large circular buildings (Thatcher's Association of South Africa, 2016).

Figure 3.31. Rafters resting on ring beam, (source: author's photograph, 2015).

3.18.4 *Thatching*

Thatch is a very common roofing material in rural areas. It has good thermal insulating qualities and helps to maintain relatively uniform temperatures within the building, even when outside temperatures vary considerably. Several plant materials, such as grass, reeds, papyrus, palm leaves and banana leaves are suitable and inexpensive when locally available. Although the materials are cheap, thatching is rather labour intensive and requires some skills as rain splashing on the roof is not common, but during long, heavy rains there is some leakage (Thatcher's Association of South Africa, 2016).

Figure 3.33. Hut position showing points of light penetration, (source: author's photograph, 2015).

The durability of thatch is relatively low. In the case of grass, a major repair will be required every two-three years, but if this was well laid by a specialist, it can last for over 20-30 years (The Scottish Vernacular Buildings Working Group, 2012). Although simple, the structure must be strong enough to carry the weight of the thatch. The use of thatch is limited to rather narrow buildings. The minimum slope for thatch stated by Devon County Council (2003) is 1:1. The slope is increased to improve the durability and reduce the risk of leakage due to water retention. The use of straw reduces the speed of fire.

African thatch has natural insulation qualities and high insulation value that provides the coolest shade in hot weather and retains heat in cold weather. Thatch's natural characteristics also provide 100% UV protection (Manning, 1995). The only set-back in using thatch is its lifespan, which averages between seven and eight years. It also tends to open up in very windy environments, which further reduces its lifespan (Manning, 1995). To overcome this, thick straw-like grass is substituted and extra thickness is ensured.

Grass for thatching should include:

- ✓ Hard, fibrous and tough, with a high content of silicates and oils and a low content of easily digestible nutrients, carbohydrates, starches and proteins.
- ✓ Free of seeds and harvested at the correct time.
- ✓ Straight and have thin leaves >1 m long.

An example of proper thatching

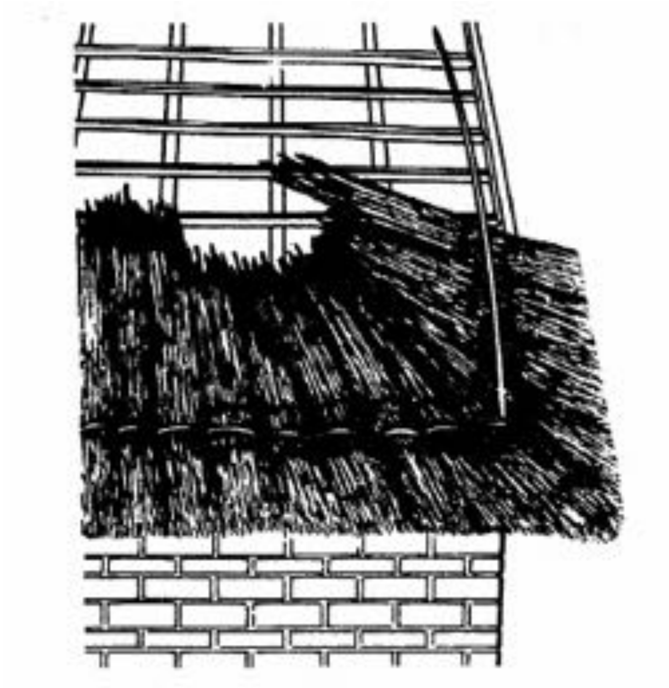


Figure 3.34. An example of thatching, (source: Manning, 1995).

Laying the thatch

Bundles of ready to use grass are carried up to the roof and placed near the thatcher for use. For convenience, a small cradle-like support that hooks to the roof structure may be used to stop bundles from falling back to the ground. Proper thatching procedure requires that:

- Stems are parallel, densely packed, with the cut side pointing outward (Figure 3.32).
- A steeply sloping roof frame of 45° is used.
- The eaves are low to give protection to the walls.
- For best outcome, the roof shape is conical.

For easy handling, the grass is tied into bundles. The thatching is started from the eaves in widths of ~1 m. Several grass bundles are put next to each other on the roof, with the base of the stems to the bottom. The grass is tied to the purlins with galvanized binding wire. In subsequent layers, the bundles are laid to overlap the layer underneath by half to two-thirds of their length, which means there will be two to three layers in the finished thatch measuring ≤200 mm.

Figure 3.35. Bucket for capping roof top, (source: author's photograph, 2015).

Table 3.1. Minimum pitch requirements for roofing materials

Roof Covering	Angle (°)	Slope	Rise (mm/m)
Built-up bitumen felt	3	1:20	50
Corrugated metal sheets (min. 150 end laps)	12	1:5	200
Corrugated metal sheets (min. 100 end laps)	18	1:3	300
Corrugated asbestos cement sheets with 300 mm end lap	10	1:5.7	180
Corrugated asbestos cement streets with 150 mm end lap	22.5	1:2.4	410
Single lap tiles	30	1:1.7	580
Plain tiles in burnt clay	40	1:1.2	840
Slates min 300 mm wide	25	1:2.1	470
Slates min 225 mm wide	35	1:1.4	700
Shingles (wood)	35	1:1.4	700
Thatch of palm leaves (Makuti)	34	1:1.5	670
Thatch of grass	45	1:1	1000
Stabilized soil	9	1:6	170
In-situ mud (dry climates only)	6	1:10	100
Fibre-cement roofing sheets	20	1:2.8	360
Concrete tiles, interlocking	17.5	1:3.2	320

(Source: FAO, 2014).

The bundles of grass are placed to the roof, a stepped surface. The thickness of the thatch layers varies between 15-20 cm, but later on this will become somewhat thinner because of settling.

The layer underneath should be half to two-thirds of the length, which means there will be two to three layers in the finished thatch. Galvanized barbed wire string is pushed through the bundles of grass onto the roof-laths about three times and tied properly. Then the bundles themselves are untied and the grass is slightly pushed into the right position, giving the roof a stepped surface. A plastic bucket was placed on the roof head to stop water collection in thatch (Figure 3.35). The roof structure and grass thatch used for the covering of the roof is 45^{o} used to optimize function (Table 3.1) (FAO, 2014).

CHAPTER 4 : RESULTS AND ANALYSIS

4.1 Introduction

This Chapter presents the results of the two-phased research that was conducted to investigate the impact of CC and adaptation responses on the existing vernacular buildings of the '*Tivs*' of West Africa. The Chapter summarizes primary data with the aim of investigating the factors responsible for the results. Further analysis of key indicators of CC are carried out to compare the response of a prototypical hut to the case study (*Tiv* traditional hut). Common indicators are:

- Temperature.
- Flooding.
- Rainfall**.**

The controlled hut was built incorporating new standards based on desktop study, questionnaire, survey and observation. The indicators of CC such as rising temperatures, flooding on the controlled and the study case unmodified hut were monitored and compared. The comparison was used to measure the benefits of adapting and provide information for people of the community who were willing to adapt. The Chapter is organized in sections covering:

1. Socio-demographic data of the sampling population.
2. Assessment of respondents' knowledge of hut building.
3. Building material and maintenance culture.
4. Analysis of historic climatic data, temperature and rainfall.
5. Historic data comparison with current data.
6. Multi-criteria analysis of adapting the *Tiv* traditional hut.
7. Results of indoor temperature readings of the adapted versus the unmodified hut.
8. Results of Analysis of Variance.

Survey/Observation

Three types of architecture were identified by observation.

The communal sit out areas (Figure 4.1) can be referred to as an assembly hall for neighbours and visitors to visit and chat. It is open all the way round to allow in daylight and fresh air. It is typically used during mild rain and harsh sunshine in the absence of natural shading.

Figure 4.1 Crops and Tuber structure/bedrooms and communal Sit out structure, (source: Ikejiofor, 1999).

4.2 Social demographic data

4.2.1 *Socio-economic scenario*

Socio-economic scenario is used in this assessment of CC impacts and adaptation to: Characterize the sensitivity, adaptive capacity and vulnerability of socio-economic systems in relation to CC (Carter *et al.* 2001).

4.2.2 *Demographic data*

Table 4.1. Demographic data of total respondents

Male	**180**	
Female	70	
	Total Number of respondents	**= 250**

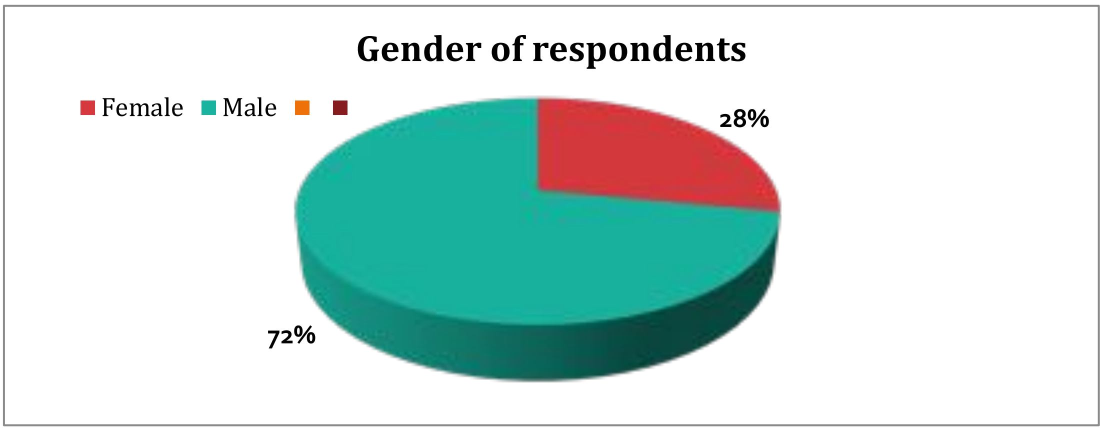


Figure 4.2. Gender of respondents.

An overview of the socio-demographic characteristics of the population picked at random showed that the community had more men than women, with 72% male and 28% female. The sampling area was largely a residential area with small business and several government offices and a church. Some 250 questionnaires out of 300 (85%) were analysed (Table 4.1, Figure 4.2).

4.2.3 *Age group of respondents*

Table 4.2. Age group of respondents

18-29	**40**	
30-45	100	
44-60	70	
≥61	40	
	Total Number of respondents	**= 250**

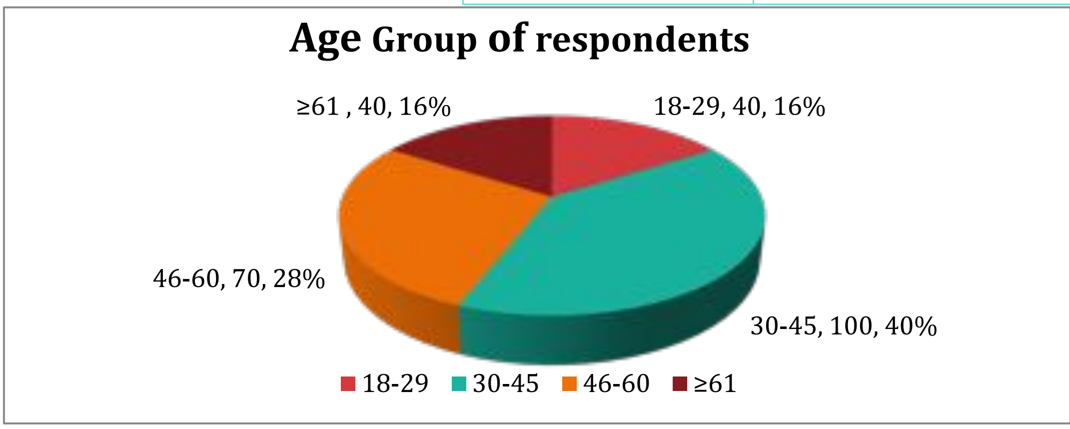


Figure 4.3. Age group of respondents.

Evidence from Figure 4.3 and Table 4.2 show that the middle age class of 30-45 with 40% were largely more active in building in the community than the other age groups.

4.2.4 *Ethnicity of respondents*

Table 4.3. Ethnicity of respondents

Tiv	**172**	
Idoma	62	
Igede	20	
Etilo	5	
Others	1	
	Total Number of respondents	**= 250**

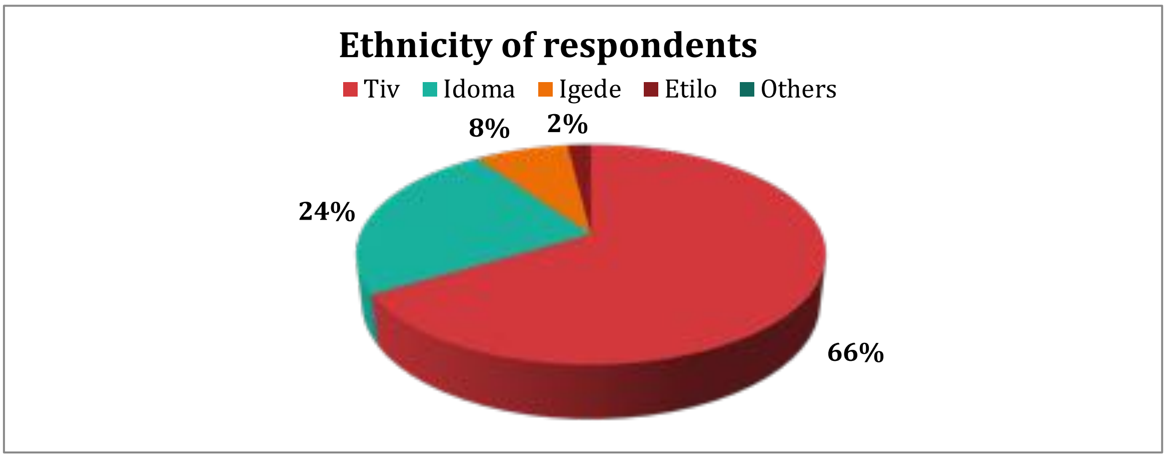


Figure 4.4. Ethnicity of respondents.

The hut under investigation are mainly occupied and built by the *Tivs* (Table 4.3, Figure 4.4) showing 66% of respondents were *Tivs*, 24% Idoma, 8% Igede and 2% Etilos. To obtain a wide range of data, it was important to cover all ethnic groups in the community to attract variety of respondents drawn (Peersman, 2014).

4.3 Respondents' occupation

Table 4.4. Occupation of respondents

Civil Servant	62
Builder	50
Farmer	80
Business-man	40
Others	18
Total number of respondents	**= 250**

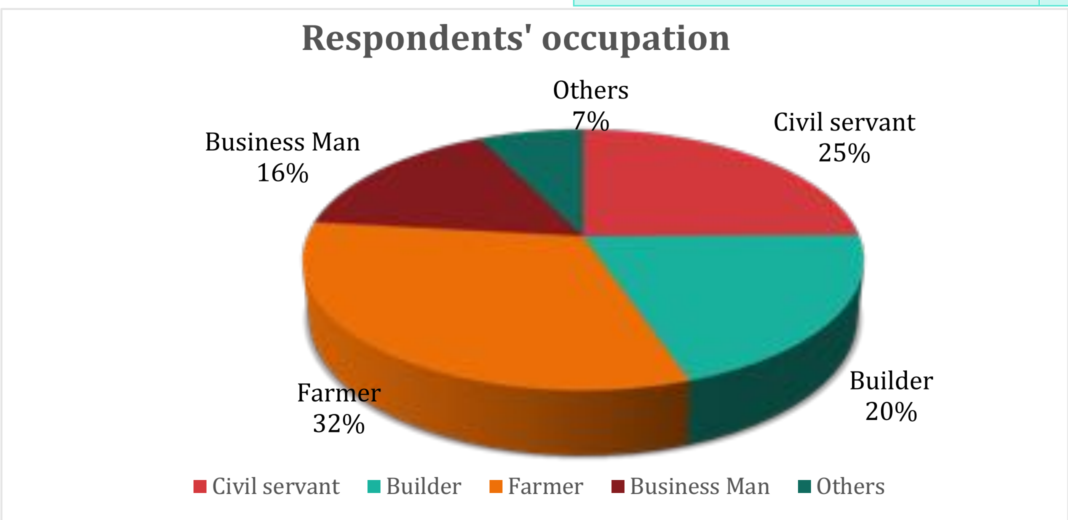


Figure 4.5. Occupation of respondents.

To gain insights into the community that has had minimal or no changes to their existing hut, data on their occupation was collected to evaluate economic factors. Typically, people with better jobs had a different approach to handling CC to people who did not have jobs or well paid jobs. It was observed that the highest number of people who used professional builders and had less renovation or repairs were business men (Table 4.4). The category with the most repairs was the 32% farmers who all had repairs carried out every year, followed by the civil servants with 27% having major repairs (Figure 4.5).

4.3.1 *Income per household per annum*

Table 4.5. Income per household per annum.

Number of respondents	Annual income (Naira)	Annual income ($)
128	150-250,000	317-527
53	250-350,000	527-738
28	350-450,000	738-1248
41	≥450,000	≥1,248
$1=266 Naira December 2015		

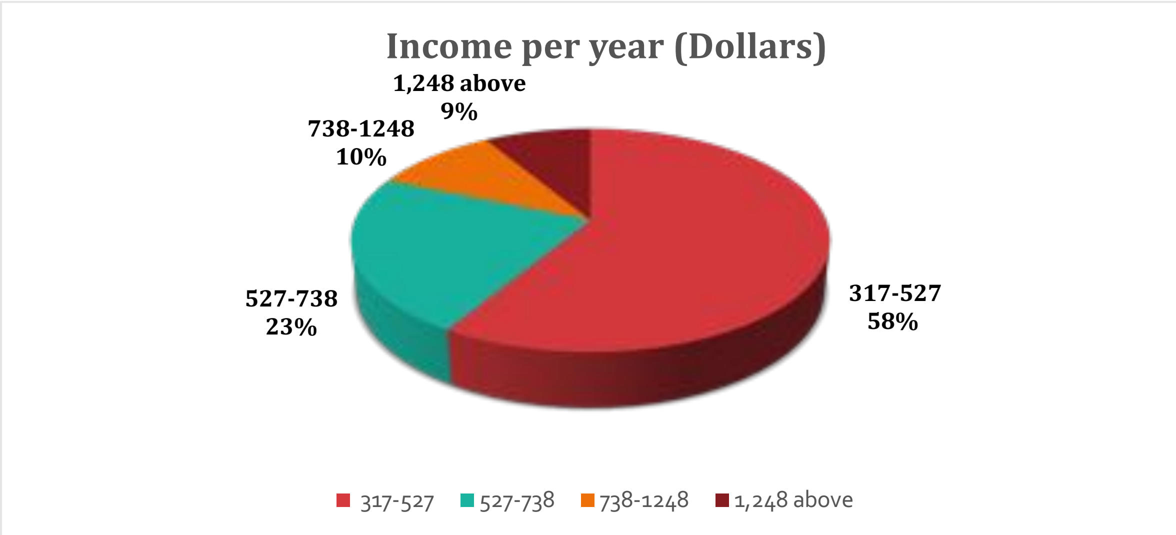


Figure 4.6. Respondents average annual income.

High-income earners were least worried about CC. They were not fearful about its occurrence, because they had the ability to adapt. On the other hand, low-income earners were most fearful of its occurrence. In other to roughly determine the adaptive capability of the respondents, data were gathered on income per household (Table 4.5). Data in Figure 4.6 indicates the income bracket of respondents. It was observed that 19% of respondents with $738-1248 and ≥$1248 respondents were business men with the highest per annual income. This shows that income per annum of households' impact their ability to adapt.

4.4 Assessment of respondents' knowledge of hut building

Results of these assessments were designed to assess the level of understanding of respondents of the '*Tiv*' hut, include material choice, building and maintenance costs. Of the 250 responses gathered in the main survey, 227 (91%) were received on this question (Table 4.6). Total missing data were 23, equivalent to 11% of total responses. Depending on whether they had built a hut, if they owned a hut and their commitment to maintenance based of other questions, they were classed as having significant knowledge of the hut. This group of respondents with knowledge and ownership formed most of the focus group (Figure 4.7).

4.4.1 *Respondents hut ownership status*

Table 4.6. Respondents hut ownership status.

Respondents who own a hut	**227**	
Respondents who do not own a hut	23	
	Total Number of respondents	**= 250**

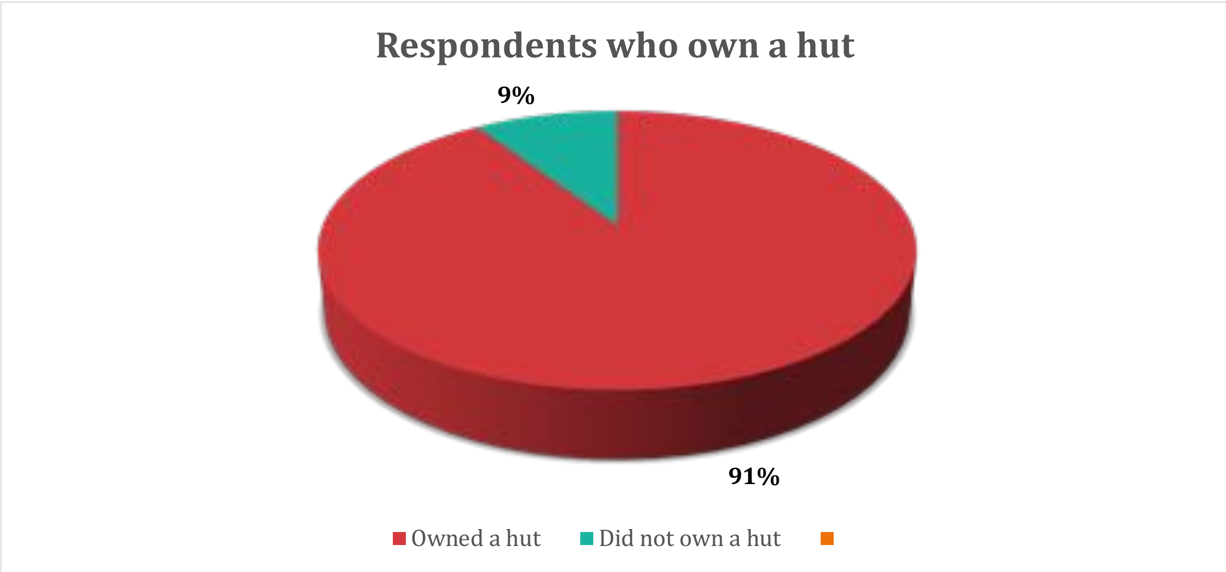


Figure 4.7. Respondents hut ownership status.

To assess the number of respondents with the most information on the hut, the percentage of people who owned a hut versus does who did not was taken into account (Figure 4.7). This information was also derived to measure attitudes towards maintenance from those who owned the hut they lived in, versus those who did not have to bear the costs of repairs.

4.4.2 *Respondents' who have built a hut*

Table 4.7. Respondents who have built a hut

Respondents who have built a hut	**196**	
Respondents who have not built a hut	54	
	Total	250

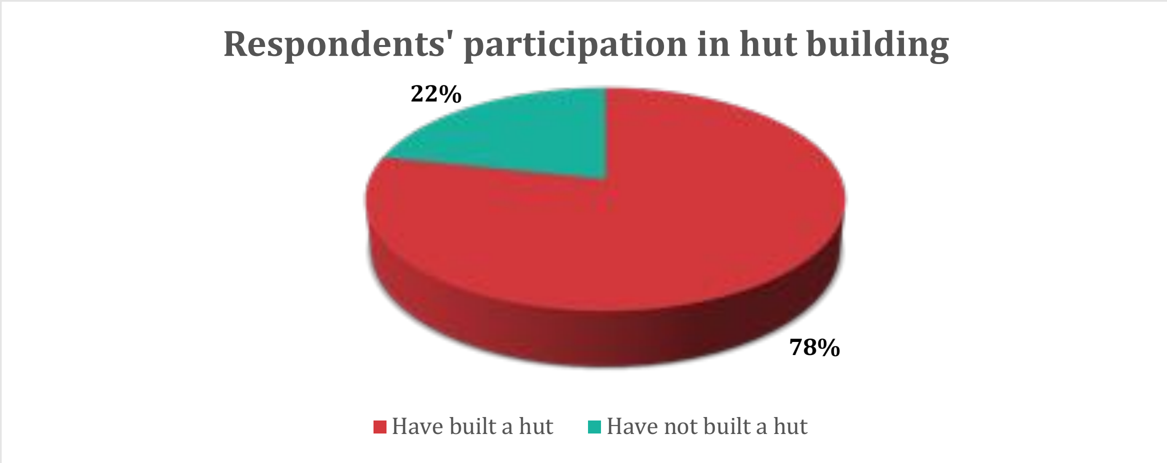


Figure 4.8. Respondents' participation in hut building.

The concerns with the current methods and materials of the existing hut were investigated (Table 4.7). Respondents were asked the question of participating in building a hut to concentrate on respondents with primary knowledge of the existing material and methods. They were also added to those classed as having significant knowledge of the hut (Figure 4.8).

4.4.3 *Respondents who thought their hut needed improvement.*

Table 4.8. Respondents who thought their hut needed improvement

Responses	Number of Respondents	
Yes	128	
No	112	
Do not know	10	
	Total Number of Respondents	**250**

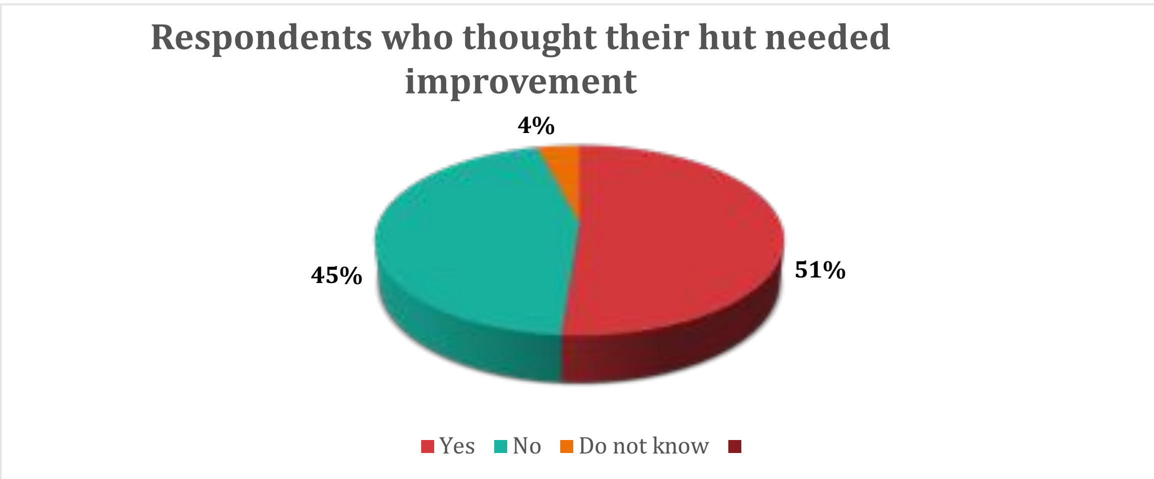


Figure 4.9. Respondents who thought their hut needed improvement.

Table 4.9 Age of the hut (years).

1-5	**8**	**3.2%**
6-10	171	68.4 %
11-15	40	16%
16-20	30	12%
≥20	1	0.4%

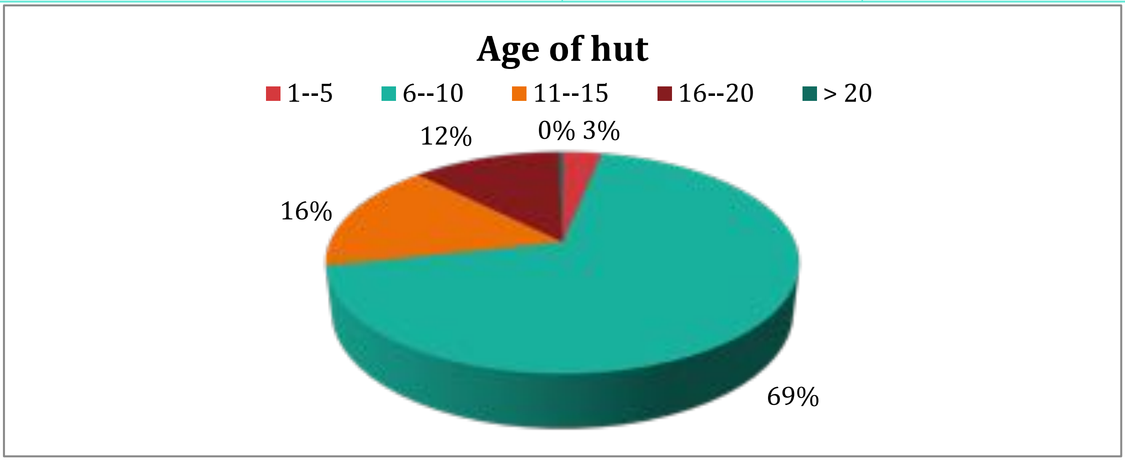


Figure 4.10. Age of the hut (years).

Fig 4.10 shows the age percentage of existing huts, some 69% of huts are aged 6-10 years, 16% 11-15, 12% 16-20% and 3% 1-5 years. To fairly evaluate the problems with the existing hut, the age of the hut is taken into account, so the comparisons are fair. It was to use the 3% which falls in the category of the adapted hut age of 3 years and 69% to make a wider comparison in terms of observation and survey. (The dollar to Naira exchange rate on 4 November 2015 was $1= ₦ 266).

Table 4.10. Price range of hut

	Naira	Dollars
90	11,000-20,000	30-56
17	21,000-30,000	58-84
37	31,000-40,000	86-112
42	41,000-50,000	114-140
55	51,000-60,000	146-168
9	Others	
Total 250		

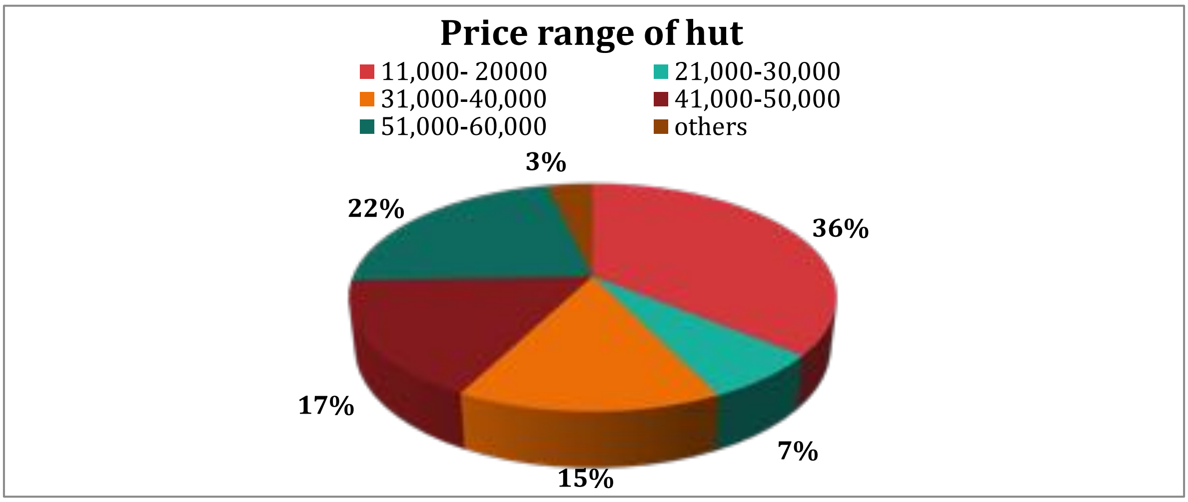


Figure 4.11. Price range of the hut (Naira).

To measure the adapting power of the respondents in respect to their annual income, data of the price of the hut was collected (Table 4.10). Some 36% was in the minimum cost range (11,000-20,000 Naira, $30-56) and 22% were in the most expensive range (51,000- 60,000 Naira, ($146-168) (Figure 4.11).

4.4.4 *Personnel who built respondent's hut*

Table 4.11. Personnel who built respondent's hut

Family and friends	179	
Self	26	
Professional builders	45	
Other	0	
	Total	250

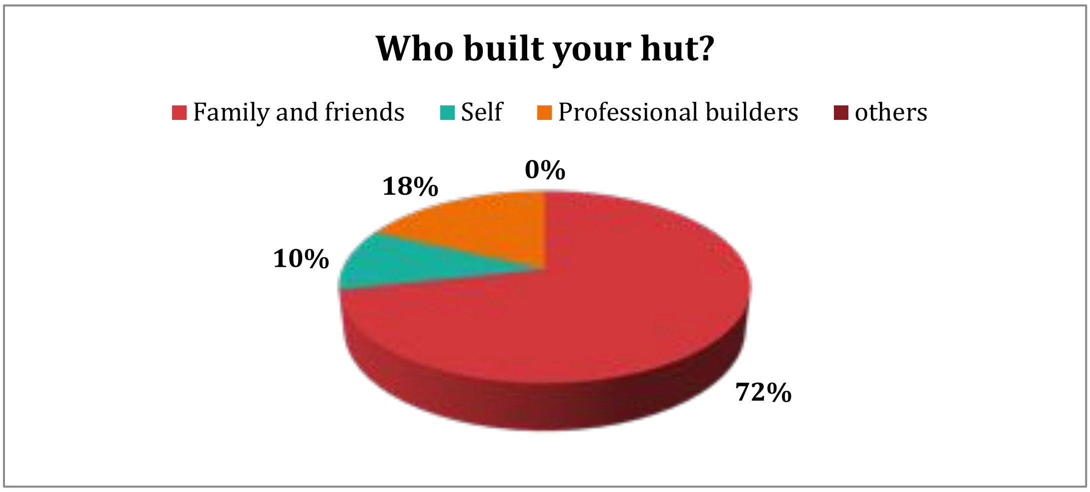


Figure 4.12. Personnel who built respondents' hut.

To gather information on material choice, design and layout, the question of who built the hut was asked to see if there were differences in the community between the huts built by professionals and those built by friends and family (Table 4.11). In this case, professional means that the builders do this for a living and have gained experience over time. Some 72% of huts were built by family and friends, 10% was built by the hut owners and 18% by professionals (Figure 4.12).

4.5 Building material and maintenance

4.5.1 *Building materials used by respondents*

Table 4.12. Building materials used by respondents

Earth	**250**
Stones	202
Bamboo	14
Straw	236
Grass	236
Aluminium/zinc	14

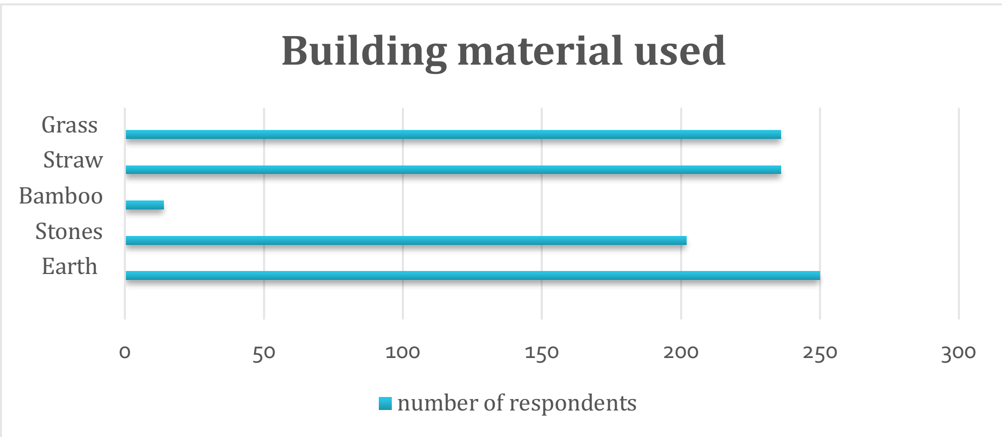


Figure 4.13. Building material used for the hut.

To investigate why different huts had different repair time intervals and features, the materials used for building were taken into consideration (Table 4.12, Figure 4.13) to explore if there were materials that had longer lifespans than these. This helped to make an informed decision on the right materials to use.

4.5.2 *Respondents who renovated/repaired their hut.*

Table 4.13. Respondents who renovated/repaired their hut

Respondent who renovated their hut		**234**
Respondents who did not renovate their hut		16
	Total Number of respondents	**= 250**

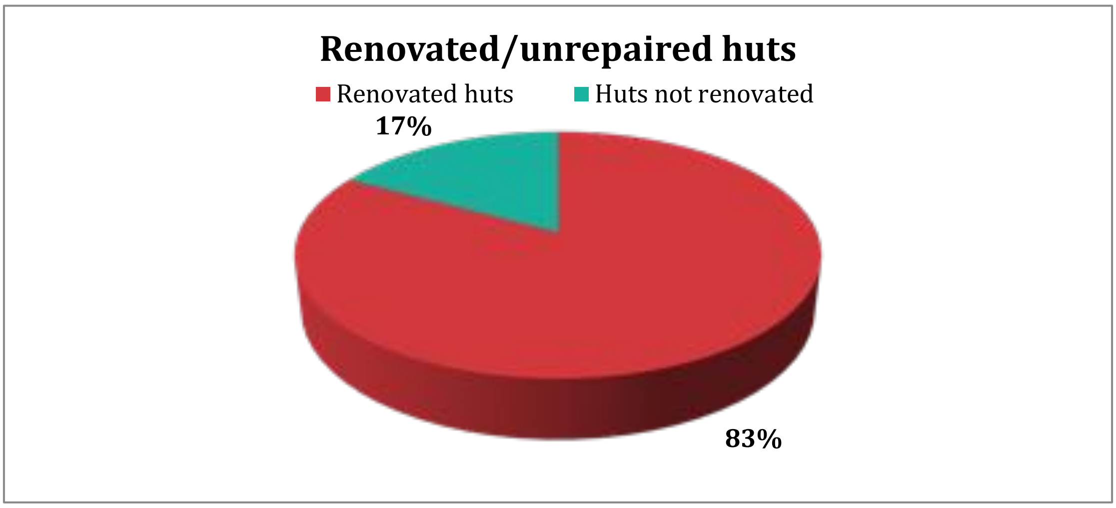


Figure 4.14. Number of renovated/unrepaired huts.

Data gathered on renovated against unrepaired hut showed that 83% of huts were renovated and 17% not renovated. All 17% of huts not renovated were professionally built. Some 16 out of the 45 were built in the same year of collecting the data.

4.5.3 *Renovated features*

Table 4.14. Renovated features

	117
External walls	192
Roof straws	146
Doors	19
Foundation wall	169
Room floor	79
Others	17

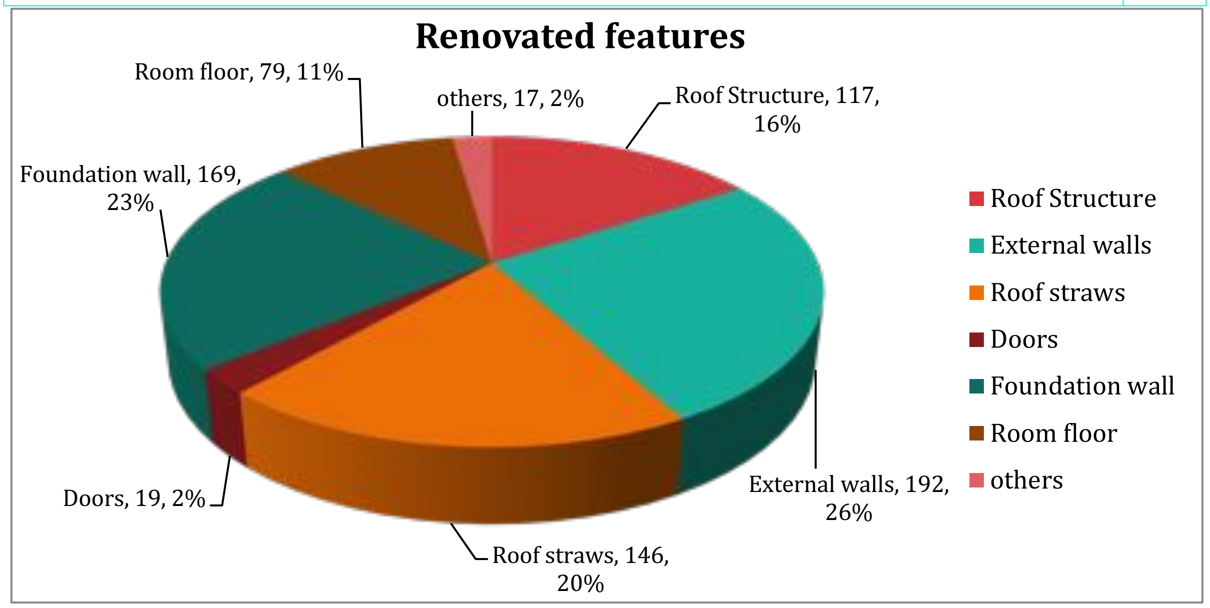


Figure 4.15. Renovated features.

Repaired features (Table 4.14) are matched with materials used for those features and how often they were used to determine if the materials have direct effect on the frequency of repairs. For this instance, all 250 respondents used earth as a walling material, but wall repairs were consistent with huts not professionally built or built with plain mud. Some 192 out of 250 reported to have repaired their external wall, 177 the roof structure, 169 foundations, 146 reported repair of roof straw and 19 repairs of doors.

4.5.4 *What were the reasons for renovation?*

Table 4.15. What were the reasons for renovation?

Flood	91
Cracks	146
Rain	117
Temperature	161
Others	3

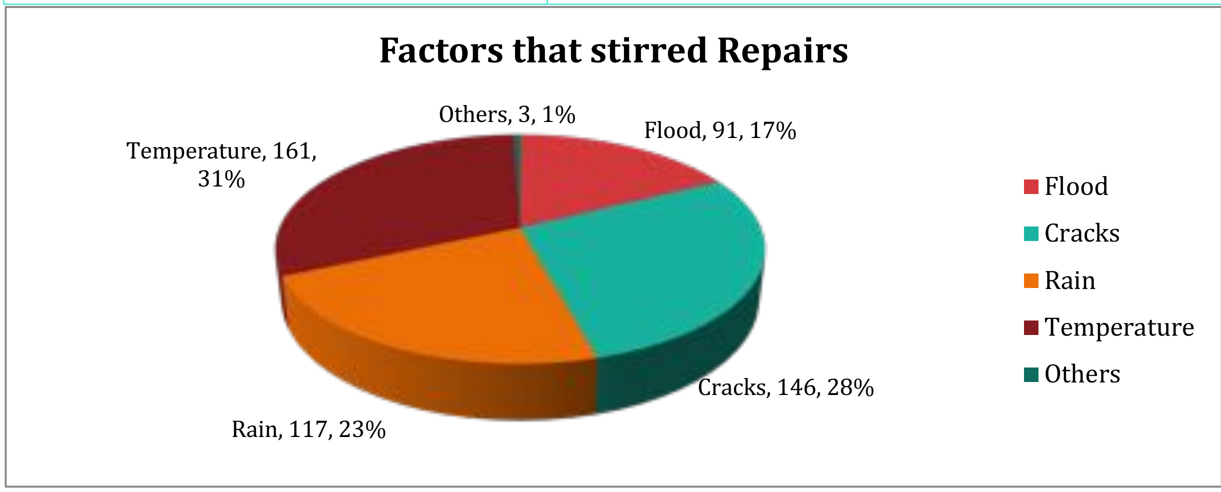


Figure 4.16. Reasons for repair.

To compare damage that necessitated repairs, data on the effect of weather on the need for repairs were investigated. Questionnaires were studied to relate these events with types of repair, to aid proper consideration of adaptation options and avoid clashing solutions. Temperature was the top cause of damage, followed by cracks, which are also an indirect result of temperature (Figure 4.16).

4.5.5 *Cost of renovation*

Table 4.16. Cost of renovation

Number of respondents	Naira	Dollars
106	3000- 5,000	8-14
98	5,100-8,000	14-17
23	8,100-11,000	17-20
22	11,100-15,000	20-47
0	15,000	0

Data on renovation costs were taken to compare the cost of the controlled hut versus the case study, which had little monetary value (Table 4.16). On average, in the fourth year of the life-span of an unmodified hut, the cost of its maintenance was greater than the cost of building the adapted hut.

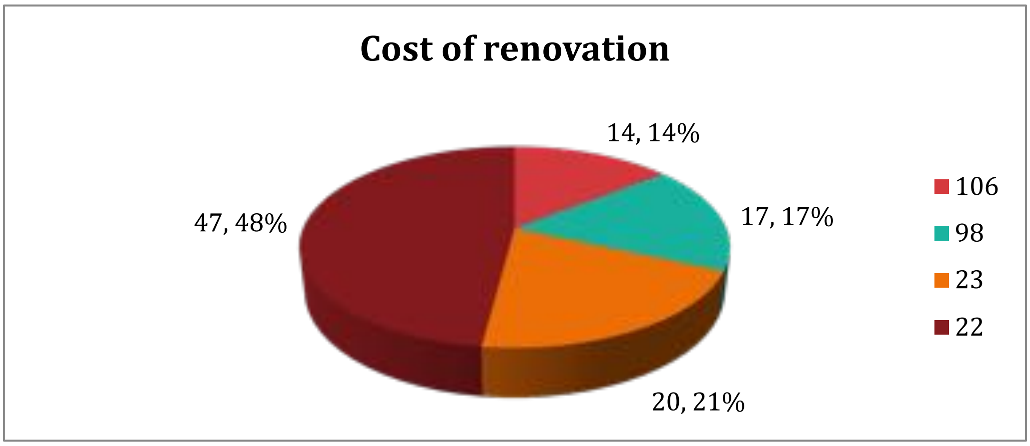


Figure 4.17. Cost of renovation.

Figure 4.17 shows that although 48% of the population in the area have a yearly renovation cost of $22, in the 4th year the cost of renovation sums is the total cost of building a fully adapted version of the hut, which is $87. Some 31% would have spent above the cost of building the adapted hut in the first year of renovation.

4.5.6 *Frequency of repair*

Table 4.17. Frequency of specific feature repair

Number of respondents	Renovation intervals		
130	Yearly		
58	Once in two years		
46	Once in four years		
16	Others		
		Total Number of respondents	250

Figure 4.18 Renovation/repair frequency.

Data collected on how often the unmodified hut was repaired show that 54% of respondents repaired their hut every year, 22% every other year and 18% once in four years. To find the reason behind the wide difference, it was observed that respondents who used professional builders aligned with the 18% who renovated every four years and six newly built huts, while 54 and 22% were all those who built using family and friends or themselves.

4.5.7 *Renovation frequency change*

Table 4.18. Renovation frequency change

Repair Frequency	Number of respondents	
Yearly	130	
Once in two years	58	
Once in four years	46	
Others	16	
	Total Number of respondents	**= 250**

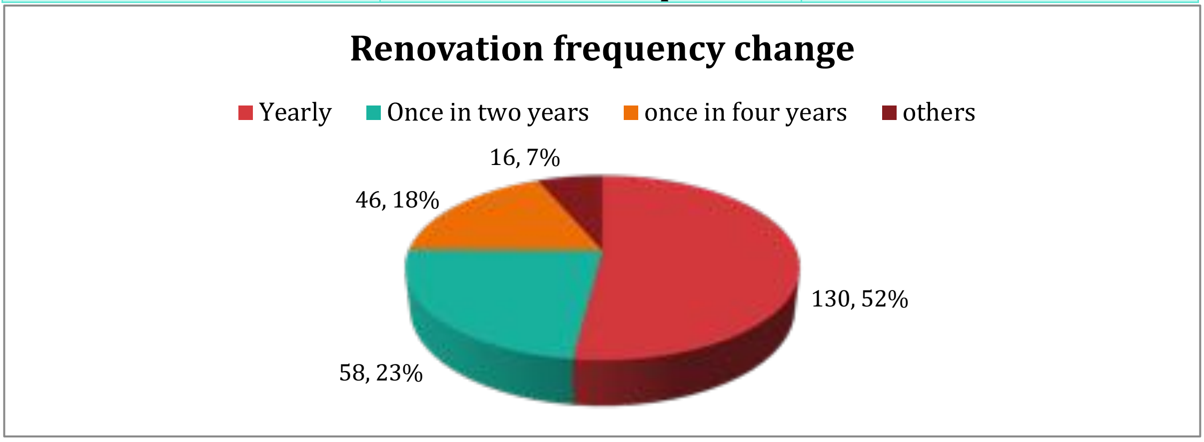


Figure 4.19. Renovation frequency change.

To find out about the impact of changing weather on the hut, data on changes in frequency of maintenance were collected (Table 4.18). Up to 55% of occupants reported that they had changed from maintenance every two years to every year (Figure 4.19). It was observed that all categories stepped up their maintenance by 50%. For instance, 24% of people who previously renovated every four years now renovated every two years, while 14% of those who renovated once in eight years now had their maintenance every four years. When asked what weather condition affected the hut most, 45% reported the cause of impact came from rain, 36% reported temperature as a factor and 19% were affected by flooding.

4.5.8 *Most impactful weather condition(s)*

Table 4.19. Weather conditions that impact the hut most

Climate impacts	Number of respondents	
Rain	112	
Temperature	90	
Flood	48	
	Total Number of respondents	**= 250**

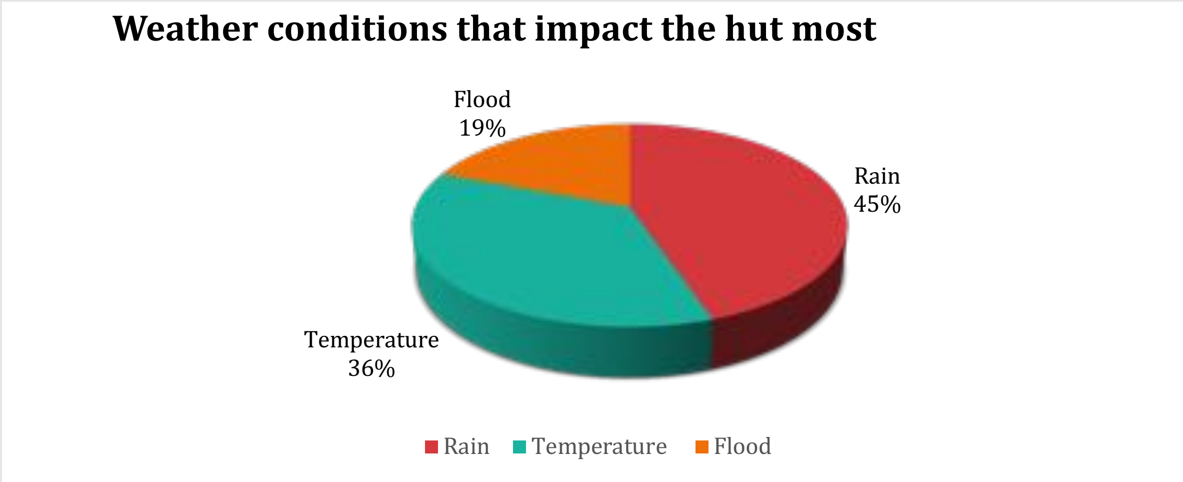


Figure 4.20. Weather conditions that impact on the hut most.

When asked what weather conditions affected their hut, 45% reported the cause of impact was from rain, 36% temperature and 19% flood. Walls are prone to cracks and surface wash after every dry and wet season (Figure 4.20).

4.6 Source of light for '*Ate*' (hut)

4.6.1 *Source of light for 'Ate'*

Table 4.20. Source of daylight for 'Ate' (hut)

Source of light	Number of respondents	
Electricity	72	
Daylight	45	
Kerosene lamps	133	
Generator	0	
	Total Number of respondents	= 250

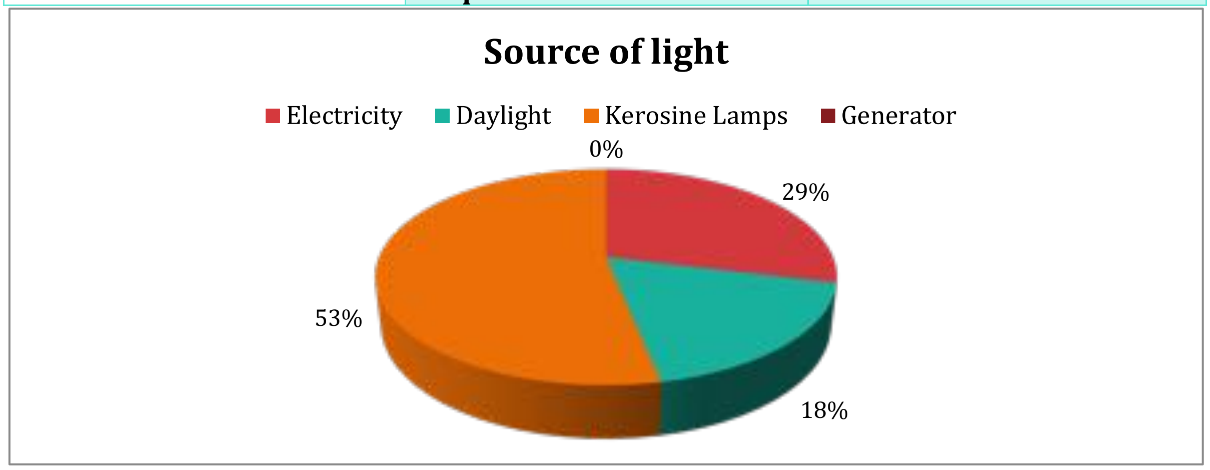


Figure 4.21. Source of light.

Some 18% of respondents had day-light access for their huts, with the remaining 82% using a form of artificial light (Figure 4.21). With this large percentage of artificial day light dependency, it was considered necessary to adapt the hut to better benefit from natural sources of light.

4.6.2 *Main source of light for 'Ate' at night-time*

To obtain an overview of the lighting of the case study, data were collected to see what made others better lit in the day. Some 82% needed a source of light other than sunlight.

Table 4.21. Source of light at night

Source of light	Number of respondents	
Electricity	90	
Kerosene lamps	142	
Generator	18	
Solar power	0	
	Total Number of respondents	= **250**

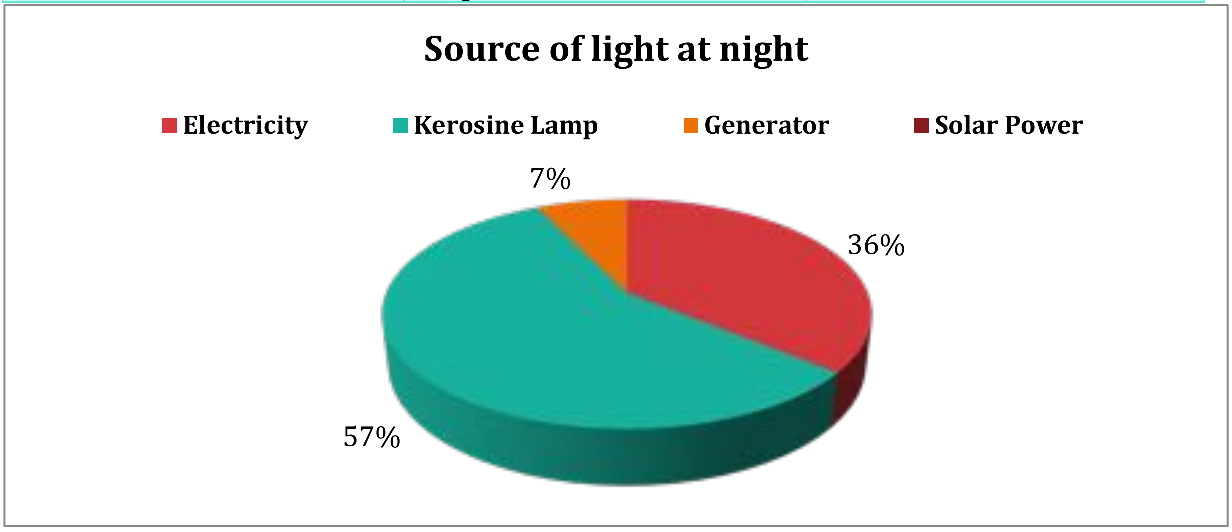


Figure 4.22. Source of indoor night lighting.

Source of light at night indicates that 57% of dwellings depend on kerosene lamps, 36% on electricity and 7% on generators (Figure 4.22). Thus, 53% of dwellings use their lamps for 24 hours a day.

4.7 Analysis

Primary and secondary data of CC impacts in the case study area are evaluated, by analysing key CC indicators and comparing the response of a prototypical hut to the case study (Tiv traditional hut) to common indicators, including:

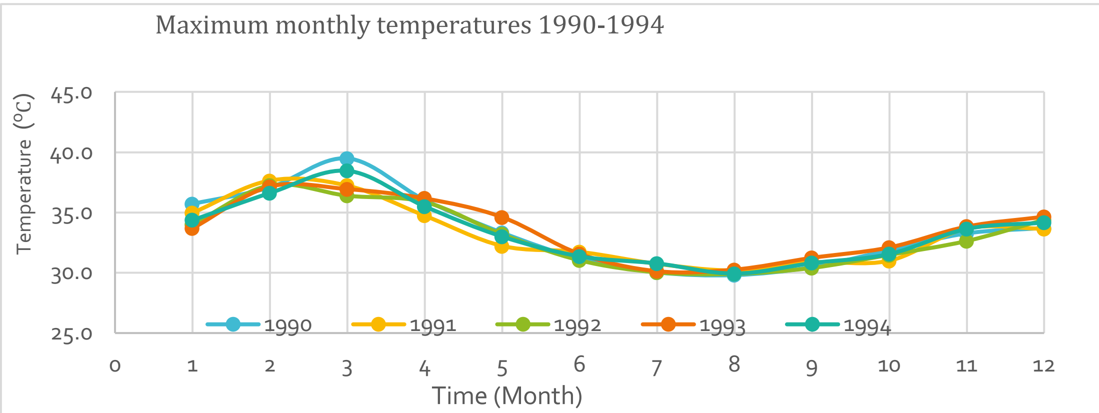
- Temperature.
- Flooding.
- Rainfall.

Estimates of the climatic monthly temperature, rainfall and humidity data record for Makurdi obtained from NIMET were used in reviewing how the area will respond to future CC and what possible adaption responses can be applied. Spatial interpolation of monthly temperature records in the region is presented. Monthly empirical data averaged over 27 years were modelled with linear models. Structural analysis of mean monthly temperature revealed: (1) a decreasing trend of maximum monthly temperature. (2) An increasing trend of minimum monthly temperatures in the first and second decades and decreasing in the following seven years. (3) Longer periods of maximum heat are noted. Historical analysis revealed that, although there have been systematic changes in the average monthly temperature for almost three decades, there are fluctuations and this proves that the direction of CC is uncertain and adaption options are therefore complex.

4.7.1 *Temperature analysis.*

Indoor and outdoor air temperatures remain the dominant climatic factors affecting thermal comfort in the tropics. Adunola (2014) and Tetteh (2010) and Chanda (2006 in Tetteh, 2010) asserted that the afternoon period in the tropics is noted for discomfort due to the impact of intense solar radiation leading to high air temperatures. This consistent impact of high insolation affects buildings and largely dictates levels of indoor comfort. It has been established that buildings must provide a functionally acceptable thermal environment. The figures below show maximum and minimum temperatures for over 28 years.

4.7.2 *Maximum and minimum monthly temperatures 1990-1994*



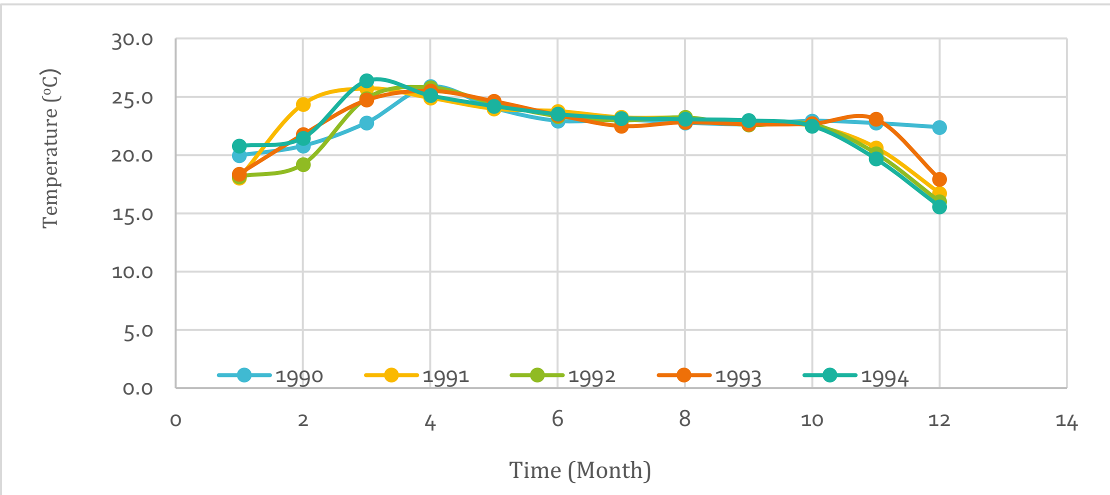
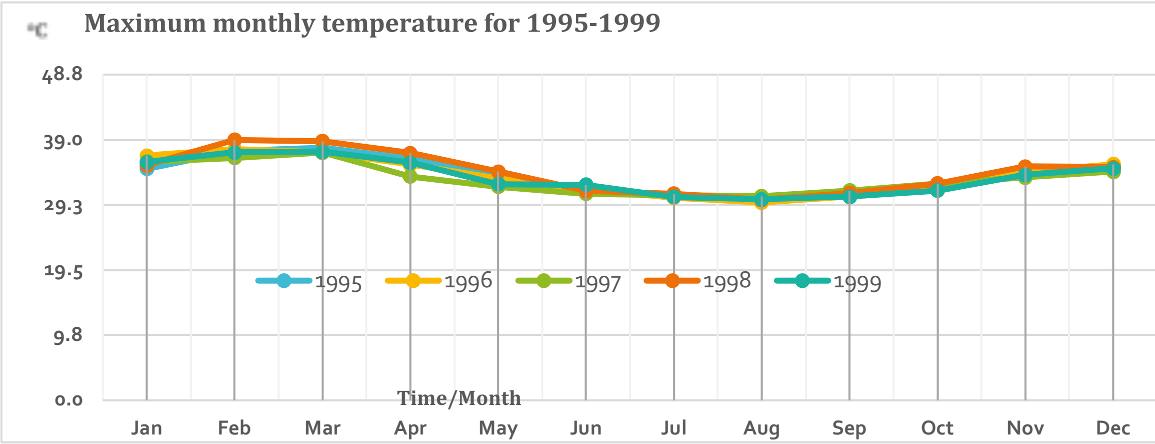


Figure 4.23. Maximum and minimum temperature, 1990-1994.

Figure 4.23 shows 39.5°C as the highest temperature for March 1990 with 29.9°C as the lowest for the period. The lowest temperature reading for the period was recorded in December 1994 at

15.6°C. Although high temperatures are seen to drop between March and September, they tend to rise consecutively from September to December for the four years.

4.7.3 *Maximum and minimum monthly temperatures 1995-1999*



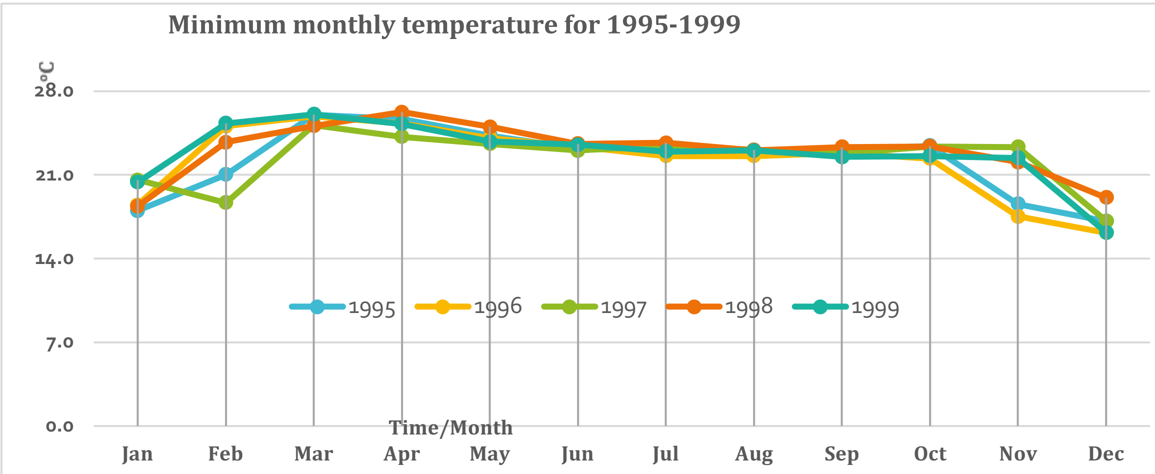


Figure 4.24. Maximum and minimum monthly temperature 1995-1999.

Maximum temperature for 1995-1999 as presented in Figure 4.24 is recorded to be 38.9°C in February 1998, with minimum temperatures in the hot seasons recorded in August 1996 (30°C). Thus, there was a temperature drop of 0.6°C from the preceding years (1990-1994). Minimum temperature for this period was recorded in 1996 December at 16.1°C. However, minimum temperatures rose from 15.6 °C -16.1°C, a rise of 0.5°C.

Fig. 4.25 shows maximum temperature of 38.5°C in 2003 between February and March (a decrease of 0.4°C). August records the lowest consecutive low temperatures ranging between 30°-30.5°C for the hot season of 2000 and 2004. The graph shows a steady decreased temperature for five years again in the months from March/April to September/October. Minimum Monthly temperature for period is recorded to be 16.5°C in January 2000 (a rise of 0.4°C).

4.7.4 *Maximum and minimum monthly temperatures 2000-2004*

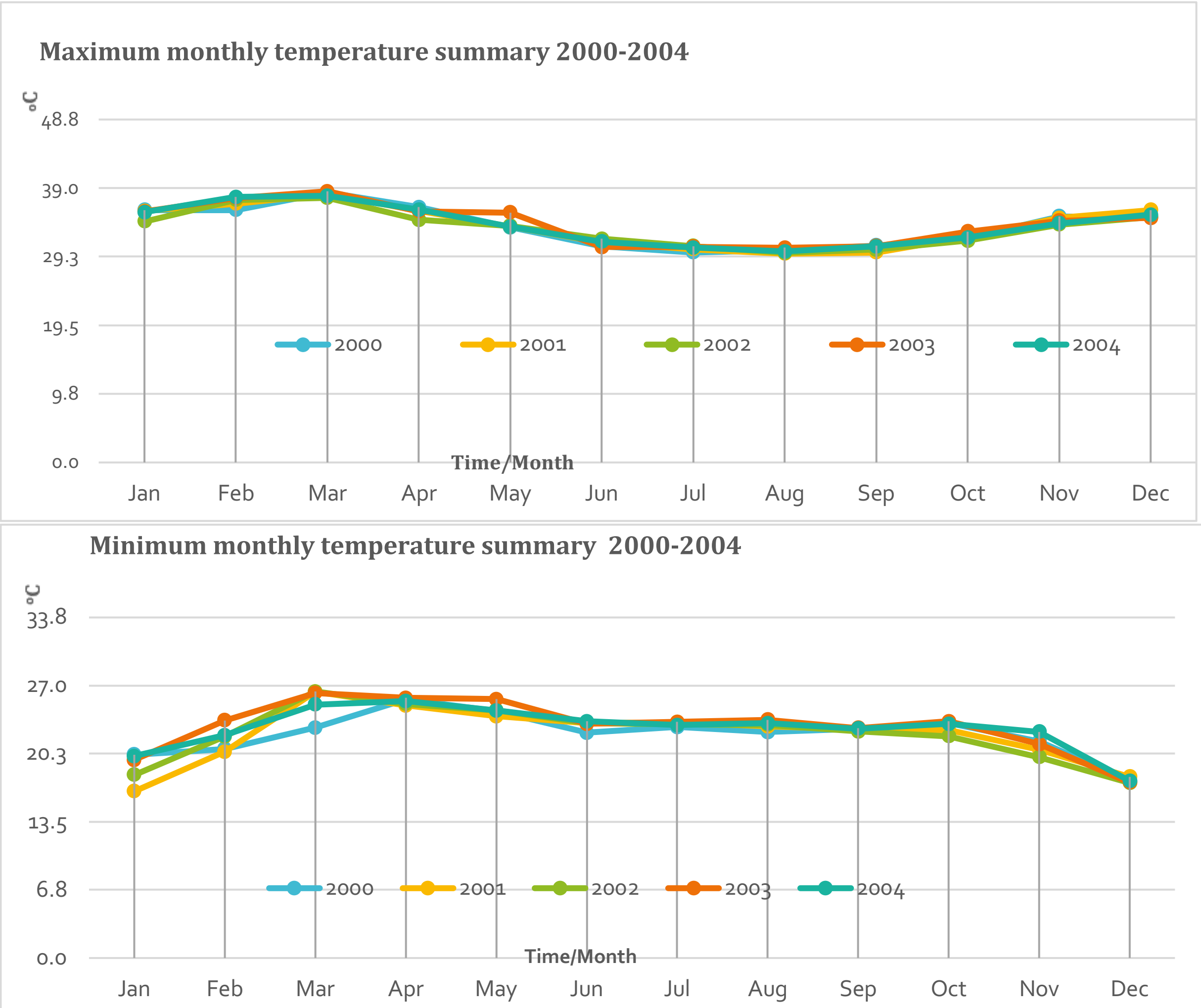


Figure 4.25. Maximum and minimum monthly temperature summary 2000-2004.

Fig. 4.26 shows a maximum temperature of 38.2°C in March 2009, a decrease of 0.3°C from the previous year. Again, August records the lowest consecutive low temperatures ranging between 30-30.5°C for the hot seasons of 2005 and 2009. (The chart shows decreased minimum temperature readings for the first time in December 2006). Minimum monthly temperature for the period was 15.6°C, with a decrease of 0.9°C. The months between February and April remained the hottest seasons through the decade.

4.7.5 *Maximum and minimum monthly temperatures 2005-2009*

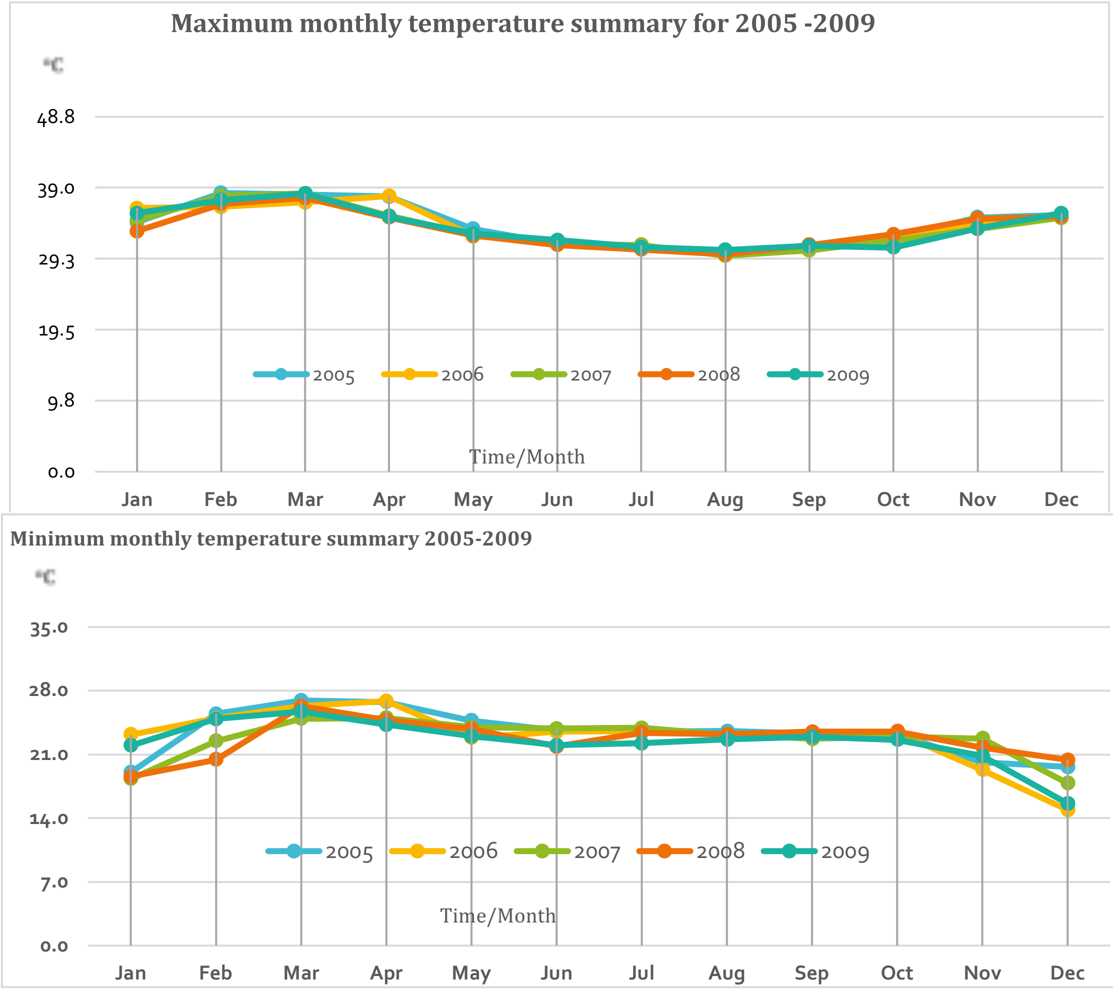
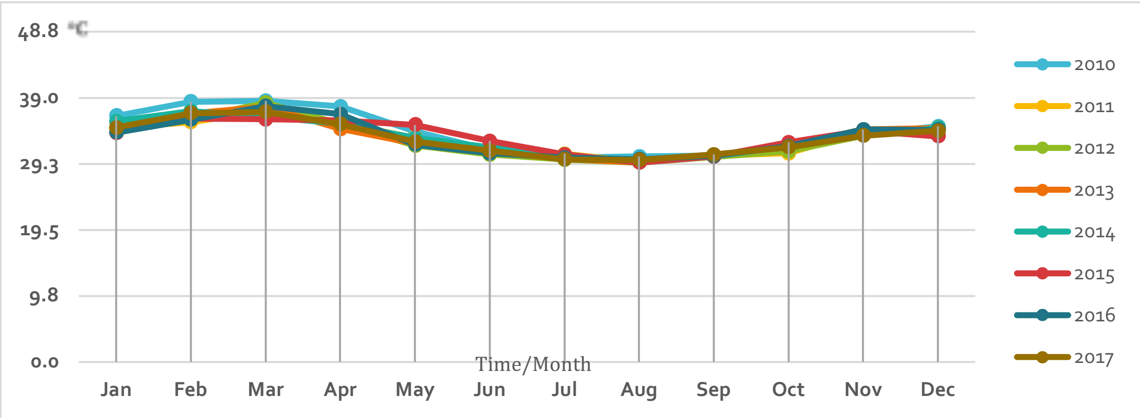


Figure 4.26. Maximum and minimum monthly temperature summary 2005-2009.

Maximum temperature (Fig. 4.27) was 38.4°C in February 2010, an increase of 0.2°C from the previous year. Again, August records the lowest consecutive low temperatures ranging between 29.8-30°C for 2010-2017. There were decreased temperatures in December 2011 (15.3°C), a decrease of 0.3°C from the previous five years.

Maximum mean temperature records during the sampling periods (November 2015-November 2017) were in the range of 34.1-33.4°C. This indicates that the November maximum was 0.7-0.9°C lower than the previous 10 year mean of 33.9°C (Figure 4.28). Minimum temperatures during the dry season ranged between 16.5-26.3°C. Minimum temperatures during this period were 0.4-0.6°C lower than the 10-year mean. Mean temperature followed the normal distribution. Maximum temperatures during the wet season period were in the range 29-35°C. Observed maximum temperature during this period was 0.5-3.5°C higher than the long-term mean. On the other hand, minimum temperatures during the wet season sampling were in the range of 21-27°C, 0.5-1.5°C warmer than the 10-year mean (Appendix 2).

4.7.6 *Maximum and minimum monthly temperatures 2010-2017*



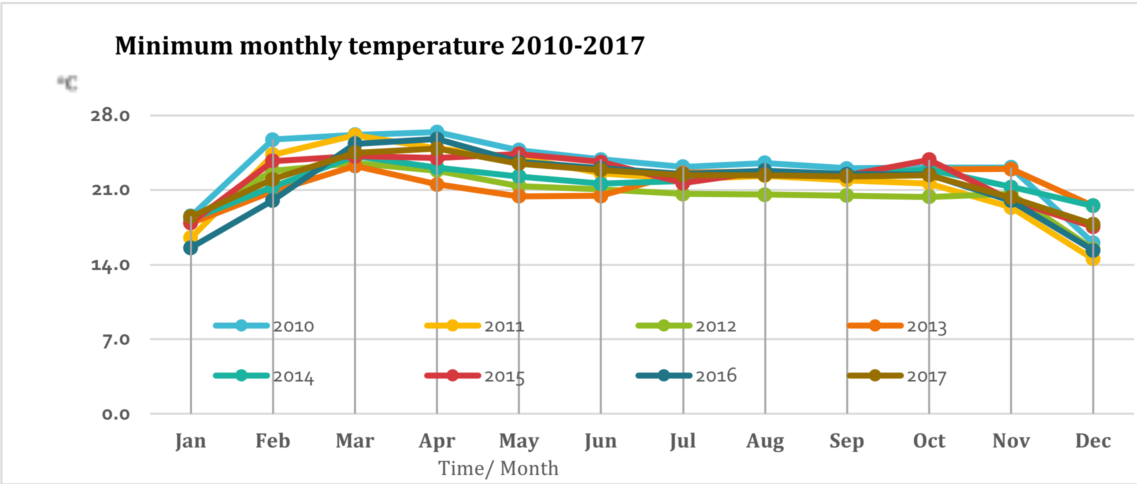


Figure 4.27. Maximum (a) and minimum (b) monthly temperatures 2010-2017.

4.7.7 *Mean maximum temperature 1990-2017*

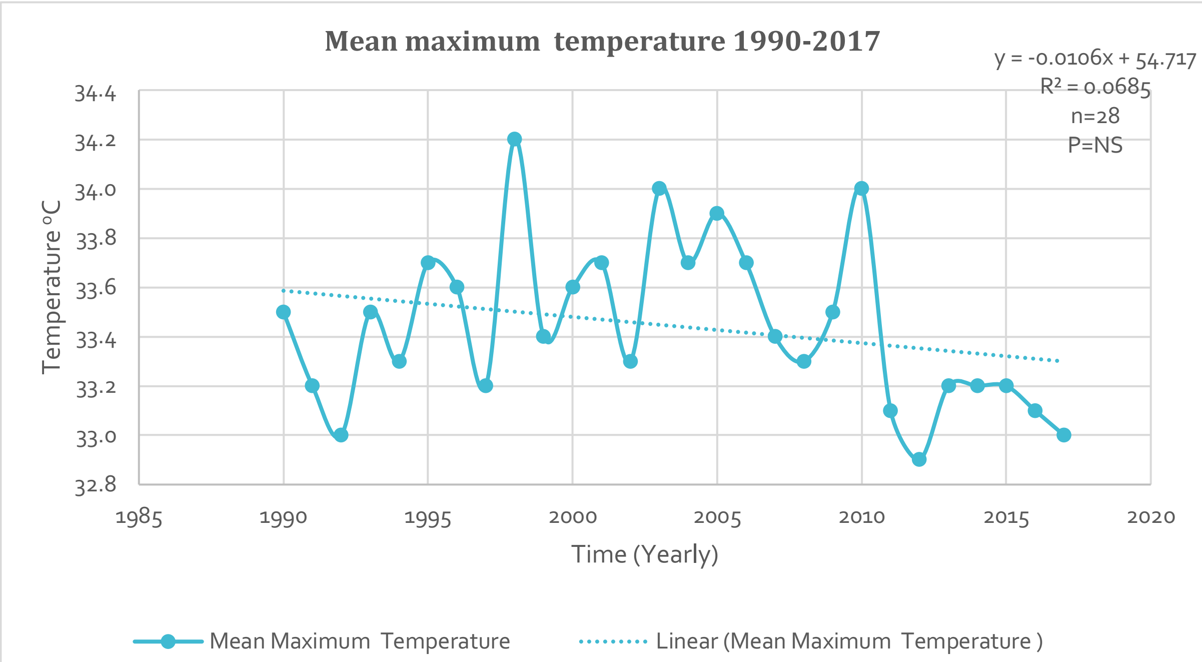


Figure 4.28. Mean maximum temperature 1990-2017.

4.8 Statistical Analysis

Monthly mean time series fluctuations were initially analysed graphically. In order to study trends in the obtained temperature series, a nine-point Gaussian filter was used to smooth the series. The test was used to detect any possible decreasing trend in the temperature series.

Highest mean temperature for the first decade ranged from 33.0-34.2°C, showing an increased temperature of 0.2°C over 10 years. The highest were between 1998 and 1999, thus, the means maximum temperature increased at 0.05°C per year with R^2 of 0.85 (Figure 4.29). Inter-seasonal variations of the mean maximum temperature for the second decade (2000-2009) show highest mean temperatures ranged from 33.3-34.1°C. This shows an increased lower temperature for the previous year from 33.0-33.3°C (0.3°C increase) and a reduced maximum from 34.2-34.1°C, with a 0.1°C decreased temperature. Thus, the mean maximum temperature increased by 0.02 °C per year ($R^2 = 0.085$, $n = 28$, P = NS).

Highest mean temperature for the third decade ranged from 32.4-34°C. This shows decreased lower temperatures from 34.1-32.4°C (2.3°C) and a reduced maximum from 34.1-32.8°C. (1.3°C decrease). This means that the mean maximum temperature increased at the rate of 0.081 °C per year, with mean of 0.32°C (NS).

Minimum mean temperature for the period of 1990-1994 was 21.8°C in November 1992, with the highest minimum recorded as 23.2°C Minimum average temperatures for the second decade (2000-2009) ranged from 22.1-23.3°C, (Figure 4.27), an increased temperature of 0.1°C from the previous decade.

Minimum mean temperature for the third decade 2010-2017 was maximum minimum temperature of 23.1°C and minimum of 20.7°C; a mean temperature decrease from 23.3-23.1°C.

4.9 Analysis of maximum and minimum mean temperatures 1990-2017

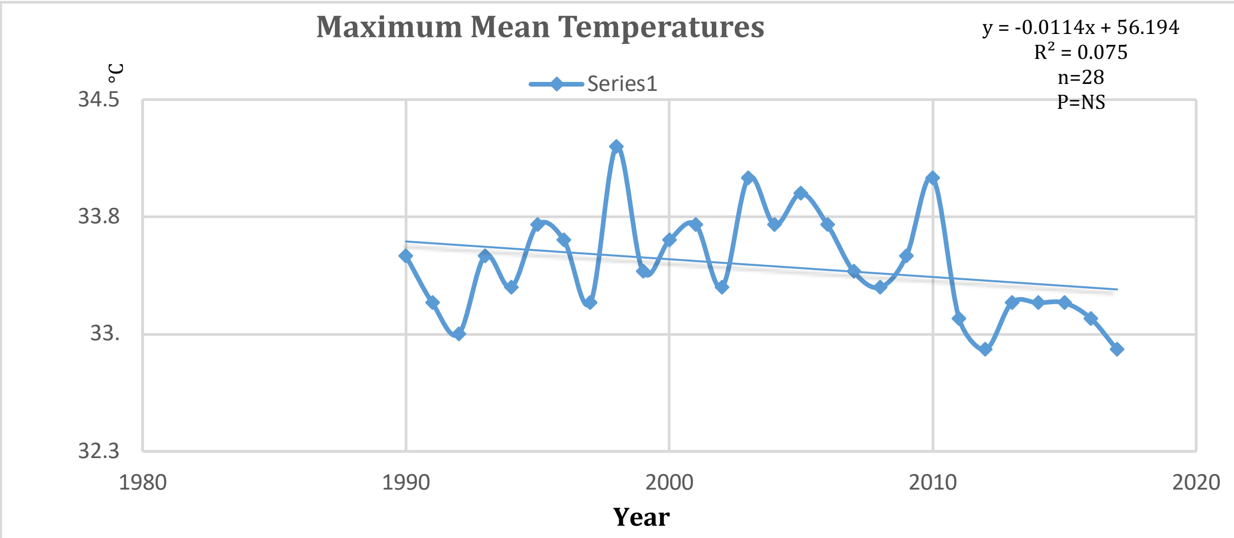


Figure 4.29. Seasonal variations of the maximum temperatures for three decades; 1990-1999, 2000-2009, 2009-2017 (Maximum mean temperature for 28 years).

The maximum temperature was high in the years 1996, 2003 and 2010. The maximum mean temperature of 34.2°C was in the decade 1990-1999. The decade 2000-2009 had a maximum temperature of 34.0°C (an approximate decrease of 0.2°C) and 2010-2017 had a maximum temperature of 33.2°C (a decrease of 0.8°C).

The 1993-2002 decade had the highest mean maximum temperature (34.2°C) followed by 2003-2012 and then 1983-1992. This implies that the 2003-2012 decade was cooler than the preceding decade (1993-2002).

There were significant differences in temperatures in the months January, February, March, November and December. Figure 4.28 show the trend analysis of the mean monthly maximum temperatures for: (a) the entire period under review (1990-2017, 28 years), (b) the first decade under review (1990-1999), (c) the second decade under study (2000-2010) and (d) the third decade of 2010-2017. Figure 4.29 gives the trend analysis for the complete 28-year period.

4.9.1 *Analysis of minimum mean temperatures 1990-2017*

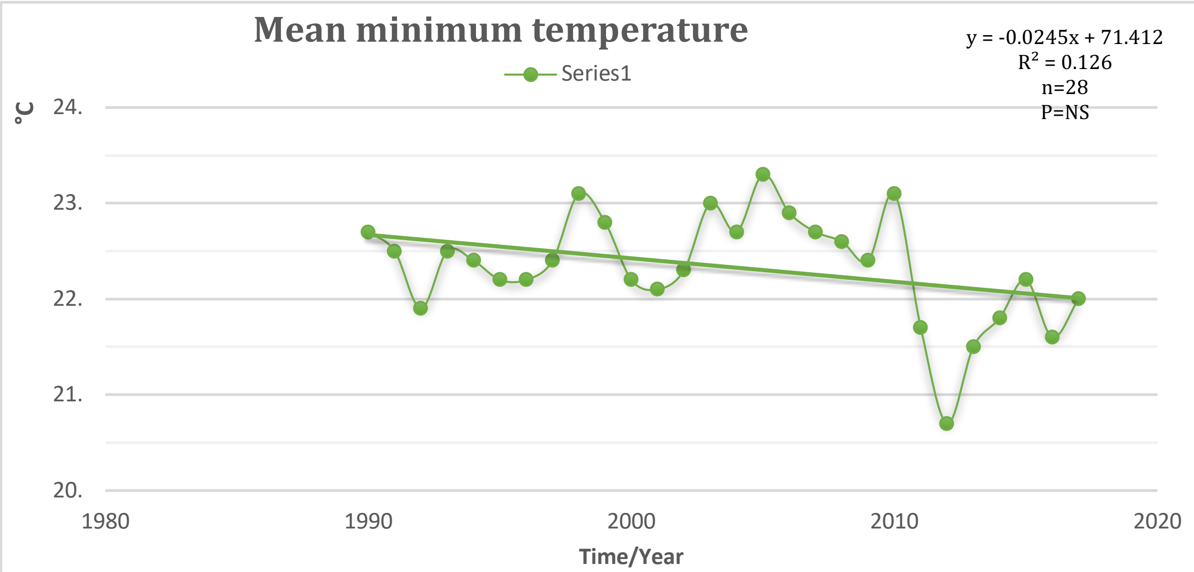


Figure 4.30. Seasonal variations of the minimum temperatures for the three decades; 1990-1999, 2000-2009 and 2009-2017 (Minimum mean temperature for 28 years).

Figure 4.30 shows the plot of the mean maximum and minimum temperatures from 1990-2017 (28 years). The mean maximum temperature was lowest in 2012 and 2017 at 32.9°C. Highest minimum temperature for the decade 1990-1999 was 23.1°C and increased by 0.2°C to 23.3°C in 2000-2009. In the next decade (2010–2017) it decreased again by 0.3°C, with 23.0°C being the maximum temperature in 2010. Lowest minimum temperatures were 20.5°C in 2012, 21.7°C in 2011 and 21.6°C in 2016.

Temperature analysis shows that there has been a widening gap in hot months. This means there were longer hotter months with temperatures >35°C. It shows a rise in minimum temperatures and a decrease in maximum temperatures, indicative of an increased number of hot days.

4.10 Rainfall analysis

The period of the dry season sampling (January-February 2017) had generally low humidity (NIMET, 2017). There was minimal rainfall during this period. The period for the wet season sampling (August-September 2016) coincided with the period of the maximum annual rainfall showed that Makurdi recorded normal rainfall for these months (NIMET, 2017), (Appendix 2), (Figure 4.31).

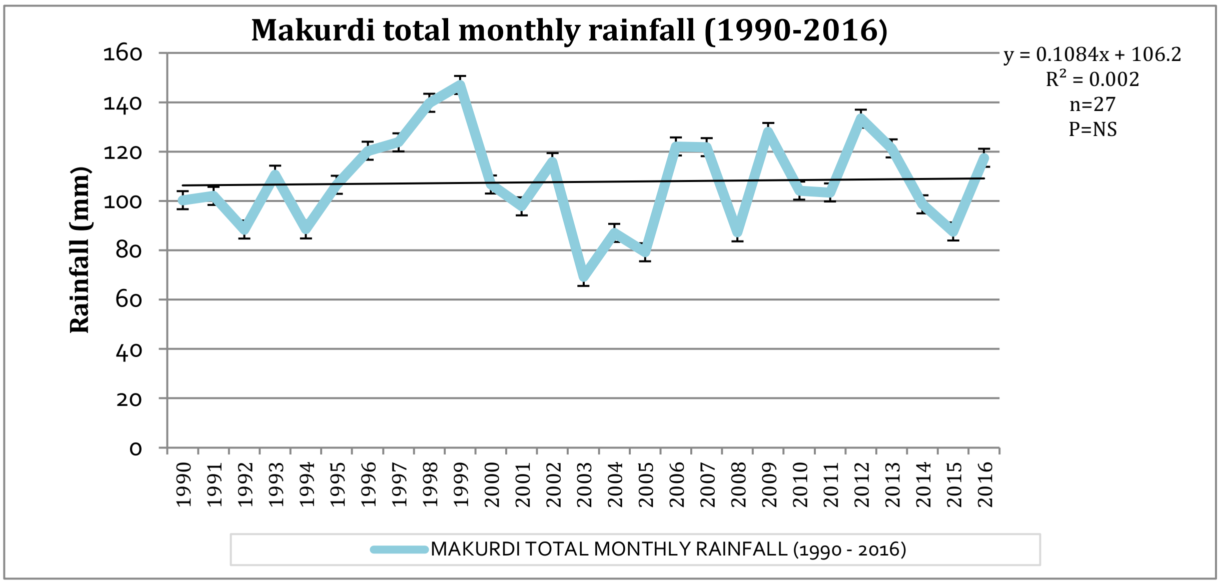


Figure 4.31. Rainfall for 1990-2016.

The amount, direction and intensity of rainfall on a building influences building design, such as roof form, flashings against the wall, storm water drainage and rainwater harvesting and cladding type, where applicable. Obtaining rainfall data for the region was therefore an important part of the preliminary design brief. Rainfall intensity varies throughout the year and from season to season, mean rainfall for the period 1990-2016 was experienced in 1999 at 147 mm. Some parts of the country have periods of intense rainfall that can be far higher than the mean (taken over a longer period of time) would suggest. Building design should be able to cope with the maximum expected rainfall (Fig 4.16) Some 47% of respondents attributed the cause of their repairs to rain and 45% reported rain as the weather parameter with most impact.In designing the building, past rainfall data were assessed to check the degree and frequency of past extreme weather events and to consider CC forecasts for the region (Jayamaha *et al.* 1999).

4.10.1 *Impact of rainfall on temperature rises*

Minimum rain was observed within the first four months of the year over 28 years endix 8.2). During the first period (1990–1994) rainfall was 80-110 mm, with 42% of the mean total annual rainfall received at 147 mm. The second period's annual rainfall received increased and averaged between 106-147 mm (1995–1999). A further increase was observed during the third period (2000–2004), where the minimum to maximum rainfall decreased from 147 to 69 mm. Rainfall slightly increased from 69-79 mm and 123 mm in 2006 and then decreased to 87 mm in 2008 and 127 mm in 2009, exhibiting rapid fluctuations. The last four years (2010-2016) showed 104-133 mm in 2012 and 117 mm in 2016.

4.11 Multi-criteria analysis

As discussed in Chapter three, to prioritize adaptation options, seven steps suggested by the IPCC, (2014) were used**.** Figure 4.32 shows a summary of the seven steps of multi-criteria analysis.

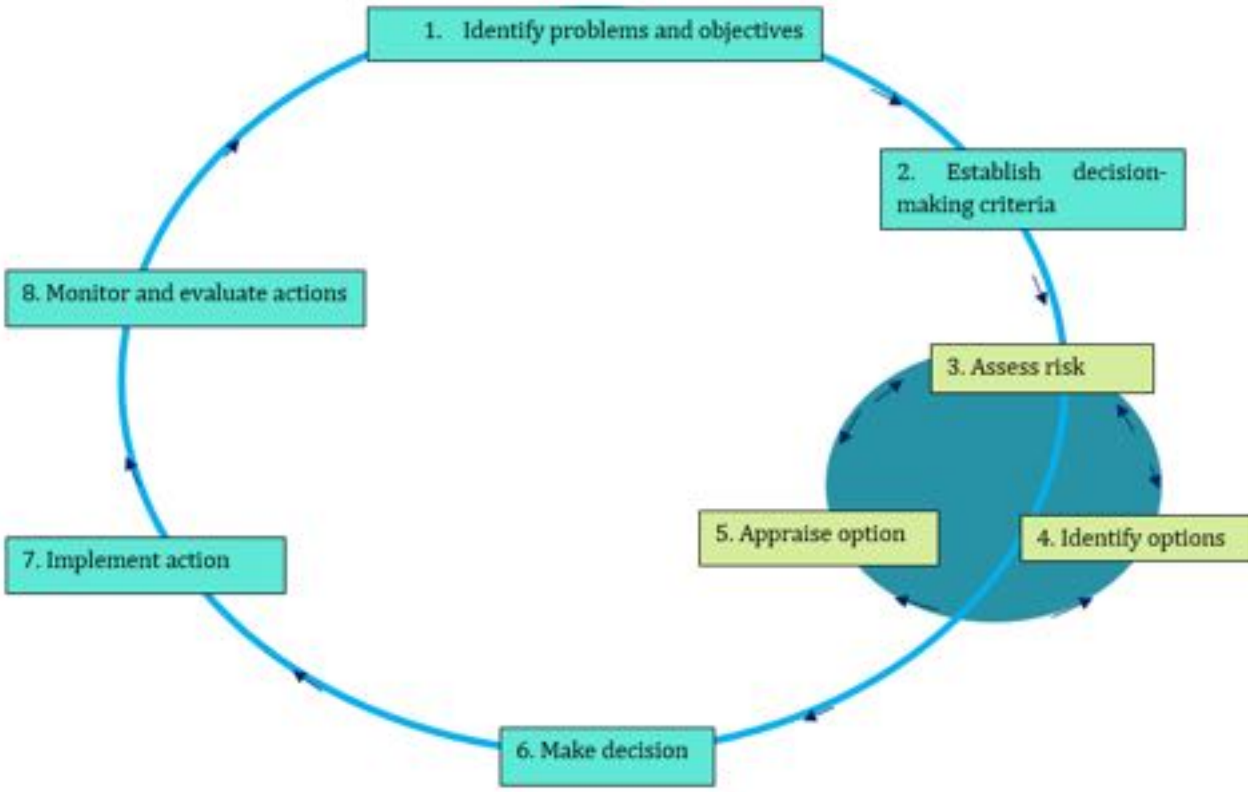


Figure 4.32. Multi-criteria analysis chart (source: adapted, Enríquez-de-Salamanca *et al.*, 2017).

4.11.1 *Adaptive measures/options*

Fankhauser (2009) investigated the history of CC adaptation and costs. Recognizing that impact approximations would be wrong if they did not include an adaptive response and challenge the hypothesis that there would be no reaction to CC. In a survey of adaptation impact models, (Tol *et al.,* 1998 in Fankhauser, 2009) concluded that many impact categories covered in the economic cost literature were actually adaptation costs, in particular flood guard and temperature controls. Adaptation strategies/options in this study consider the option of initial adaptation from the construction phase. Multi-criteria analysis was used to prioritize adaptation options (Figure 4.32). Table 4.22 details the problems and approaches to adapting to the identified problems.

- **Step 1**

4.11.1.1 Identification of adaptation options based on problem

Table 4.22 Adaptation measures for foundation

Identified problem	*Adaptation Measures/Options*
Foundation damage due to surface water runoff/erosion and flood.	Reinforcement of foundation base by using concrete and aggregates.
Water penetration.	Raised foundation height from ground level by 300 mm.

To reduce the speed of wear caused by running water and wind that cause erosion the foundation was raised and made more resistant to water penetration and erosion. Figure 4.33 show the case study and model side-by-side. Physical signs of wear are shown on the case study foundation wall and new adaptive measures for this are shown on the model.

- Raised floor levels

Figure 4.33. Unmodified versus adapted foundation, (source: author's photograph, 2015).

A survey in a rural community in Mexico by Eakin *et al.* (2016) reported a similar test. They found that during the rainy season, 66% of participants said most times they experience flood impacts in their homes and particularly the foundation. They stated that to reduce/avoid flood impacts, raising the foundation floor is an option. Eakin *et al.* (2016) stated 68% reported impacts on their homes due to rain and flood.

BBC Local (2004) reported on the cost of adaptation impacts in respect to maintenance using Bangladesh (a low-income country) as a case study area, with insufficient funds to implement large scheme adaptive measures. They concluded that it is better to incorporate adaptive measures to focus on reducing the impact from the building stage, which is usually more economical than correcting (Figure 4.34). Buildings were threatened with flooding, therefore more sustainable ways of reducing flooding were used, including building coastal flood shelters on stilts and early-warning systems (Eakin *et al.,* 2016).

Figure 4.34. Raised traditional building in Bangladesh, (source: BBC Local, 2004).

4.11.2 *Reinforcement of foundation base by using concrete and aggregates*

Reinforcement of the foundation base and elevation from ground level are possible adaptation options, as data gathered on floods and rainfall suggests (FEMA, 2014, Lyamuya and Alam, 2013). Success cases in developed and developing countries, including the USA and UK with detailed procedures for minimizing flood hazards, were imitated. For example, FEMA's guidance in identifying flood risk and determining whether a home is located within a Special Flood Hazard Area (SFHA) and what the Base Flood Elevation (BFE) to be used was applied. Data collected via surveys, questionnaires and interviews suggested that although floods were minimal, the present method of constructing foundations in the case study area are problematic, as foundations usually needing regular maintenance, especially after the rainy season. Figure 4.35 shows details of concrete foundation walls to reduce seepage (Lehner, 2006).

Figure 4.35. Concrete foundation walls to reduce seepage, (source: author's photograph, 2015).

Trees and shrubs help protect soil land from water erosion. Low-lying areas must be encouraged to use vegetation to help break the power of moving flood water and decrease soil erosion (Lehner, 2006).

Figure 4.36. Controlled project shaded by trees, (source: author's photograph, 2015).

4.12 High temperatures

Specific methods to prevent heat gain include reflecting sunlight away from the house, excluding heat, removing built-up heat and reducing/stopping heat generating sources in the home. The most effective method to cool a home is to keep the heat from accumulating in the first place (Cook, 1996). The primary source of heat gain is sunlight absorbed by the house through the roof, walls and windows. Secondary sources of heat-generating appliances in the home are considered common in the case study community. Table 4.23 shows problems and adaptation measures for room temperature control (Figure 4.37).

Table 4.23. Adaptation measures for temperature control

Identified problems	***Adaptation measures***
High indoor temperatures	Increase block size to reduce heat gain
	Increase roof density to reduce heat gain

4.12.1 *Walls as an insulator*

Figure 4.37. Increased block size, (author's photograph, 2015).

In hot regions building thick houses and courtyards help exclude hot, dusty winds. Thick walls serve as insulators against hot air. Wall thickness is increased by increasing block size from 11.2 x 11.8 mm to 13.2 x 12.5 mm.

4.12.2 *Increased roof density to reduce sun and water penetration*

Figure 4.38. Increased roof density, (author's photograph, 2015).

The base layer of the roof is formed to support the principal thatching material, prevent the thatch falling into the interior and provide additional protection to the roof structure from water and sun access (Figure 4.38).

4.13 Natural source of lighting to reduce the use of fossil fuel/ carbon emissions

Kerosene lamps are a common source of lighting in the study area and are expensive to operate, both for low income households that buy it and for governments that subsidize it, such as Nigeria. In parts of Africa, for instance, kerosene costs make up 10-25% of household monthly budgets. Thus, alternatives to kerosene lighting are an attractive area for achieving quick and cost-effective climate benefits (Tedsen, 2013). Data collected via questionnaire suggested that a mean of 54% of households in the case study community use Kerosene lamps in the day and night as their source of lighting.

Table 4.24. Adaptation measures for lighting

Identified problems	***Adaptation measures for lighting***
Insufficient natural lighting due to small windows (300/260 mm) (Figure 4.39).	Increase window size and use louvres to control sun penetration (1000 mm/900 mm)(Figure 4.41).
Low overhanging roof covering windows preventing the entrance of light.	Increase building height and decreased pitch to allow natural lighting.
	Correct window angle positioning to maximize daylight entry.

Figure 4.39. Reduced roof pitching to allow in daylight, (source. author's photograph, 2015).

Table 4.25. Annual kerosene use and black carbon emissions in Nigeria

Installed stock estimates (millions) Kerosene lamps-glass cover	Installed stock estimates (millions) Kerosene lamps-simple wick	Annual kerosene Saved (millions of litres)	Annual black carbon savings (tonnes)
Household-39.8 Businesses-3.8 43.6 million (70.7%)	Household-17.8 Businesses-0.3 **18.1 million (29.3%)**	**2300**	**52,680**

(Source*:* Tedsen, 2013).

The main sources lighting in the case study community are kerosene lamps and electricity. Indoor air pollutants in rural environments include the burning of kerosene, candles from lighting and mosquito coils. Combustion in enclosed spaces without adequate ventilation leads to higher concentrations of carbon monoxide, nitrogen oxide and suspended particulate matter Tedsen (2013). To reduce this, good ventilation is the only option.

4.13.1 *Increased hut height and roof angle to increase daylight entry*

Figure 4.40. Unmodified hut height and roof vs modified roof angle and height (author's photograph, 2015).

4.13.2 *Window positioning*

Windows are one of the most essential building components and have positive influences on the well-being of building occupants. They play an important role not only in providing daylight, ventilation and view but also in modelling the overall energy demand for the building.

4.13.3 *Window/ lighting in relation to maintaining temperature and cost*

Windows positioned towards sunrise and sunset will maximize daylight and avoid the use of fossil fuel as a source of light in the day (US Department of Energy (USDoE), 2004). USDoE suggested the option to control the amount of sunlight/air that comes into the building is the use of rolling shades made of fabrics. However, they are the most expensive shading options, but they work well and can provide security. Many exterior rolling shades can be conveniently controlled from the inside.

Figure 4.41. Controllable louvres, (author's photograph, 2015).

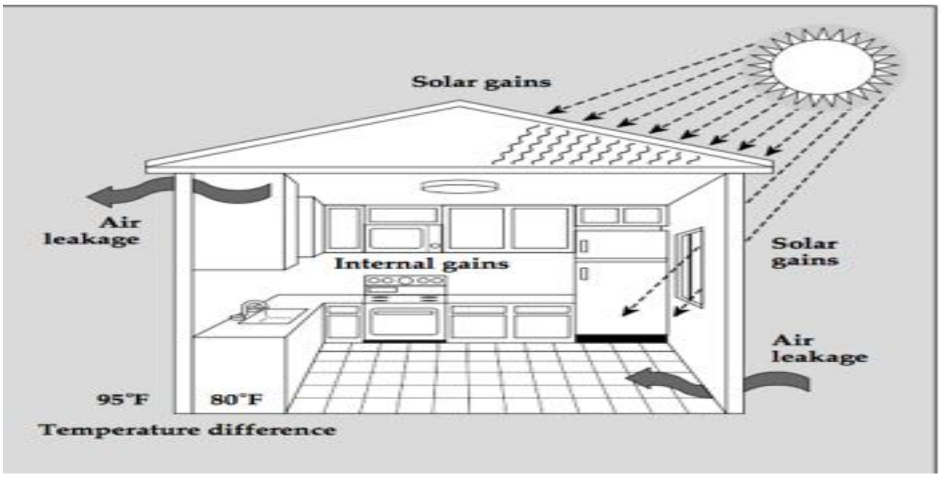
Windows are one of the most important building components. This is because they positively influence the health and well-being of building occupants (Mangkuto *et al.,* 2016). Although contradictions frequently occur when trying to maximize daylight penetration and view, which typically mean applying large windows. In trying to minimize energy consumption, usually translates to applying small windows. However, in the case study area where energy consumption is as a result of small windows, larger windows seemed most suitable.

To attain thermal comfort in cooling applications, buildings are designed to minimize daytime heat gain, maximize night-time heat loss and encourage cool breeze access when available. (Mangkuto *et al.,* 2016) Fig. 4.43 shows how heat gain and loss occurs. For breeze collection, window design is more important than direction with louvres 95% opened to air as an option. The modelled hut uses this concept (Figure 4.42).

4.14 Strategy 2: Temperature control using trees as shading

Shading can reduce indoor temperatures by 11°C (US Department of Energy, 2004) Effective shading can be provided by trees and other vegetation and exterior or interior shades.

- All walls and



windows are permanently shaded to prevent the access of sunlight and rain.

Figure 4.41. Sources of heat gain (source: US Department of Energy, 2004).

Four factors affect heat accumulation in a home: solar heat gain, internal heat gain, air leakage and temperature difference.

Buildings should be designed with controllable natural ventilation. A very high range of natural ventilation rates is used so that the heat transfer rate between inside and outside can be selected to suit conditions (Fordham, 2000). Ventilation rates are selected to control temperature, pollution and air movement. Ventilation with heat reclaim and the thermal capacity of the building are also considered. These factors are considered in building the adapted hut in the case study area. Buildings need to be designed with natural ventilation in mind to minimize the use of fossil fuel energy. Outdoor areas are shaded with plants, to lower ambient temperature, causing incoming air to be cooler.

Figure 4.42. Controlled hut showing shadings, (source: author's photograph, 2015).

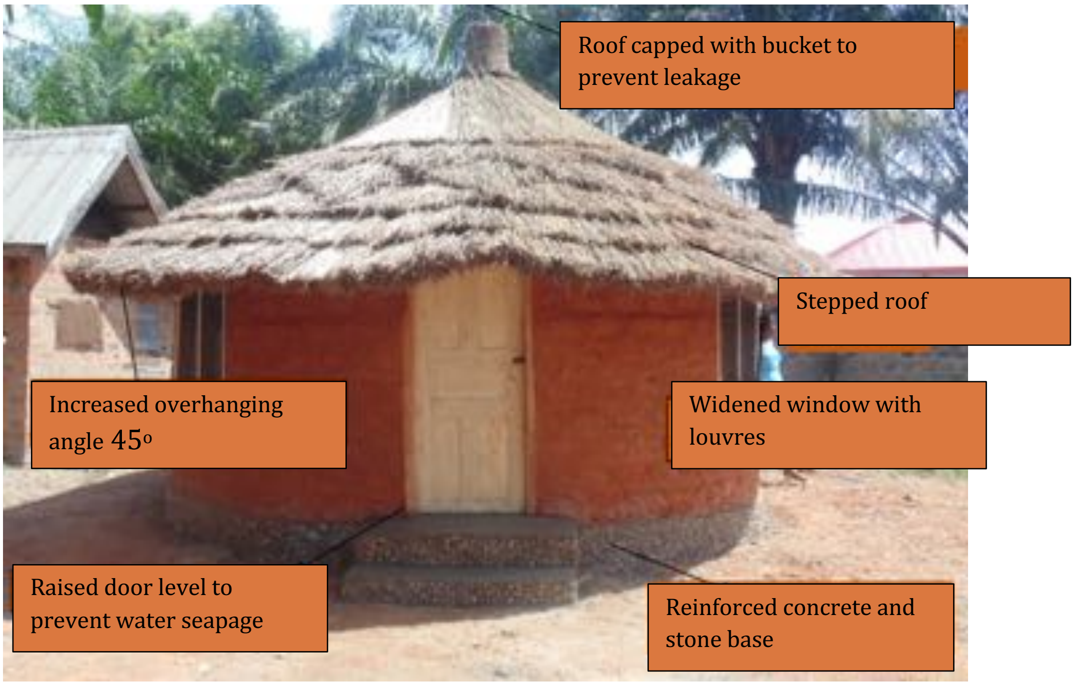


Figure 4.43. A completed model of the *Tiv* traditional hut, (source: author's photograph, 2015).

- **Step 2**

4.15 Identification of stakeholder/receptors

Stakeholders were identified through data collected via questionnaire. Out of 250 questionnaires that were collected, 200 who said they owned a hut, of the 200 10 worked in the Department for Housing and were also present for the discussion and agreed to be contacted for further participation in a focus group discussion.

- **Step 3**

4.16 Focus group discussion with stakeholders to identify and assess risk

4.16.1 *Discussion questions*

The focus group discussion gathered data on why natives build the way you do. Recorded responses were taped with their permission. Each individual stated what was important to them in the hut. Participant's responses were noted and compared to the responses of other participants.. To save time and accurately interpret responses from focus group discussions, an audio recording was used to gather information and then transcribe them later.

4.17 Coding and developing categories

Axial coding was used to organize and summarize collected information. This was to help prioritize adaptation based on scores in order of priority (Gibbs, 2014).

4.17.1 *Codes*

Table 4.26. Coding Responses

Domain	Sub Domain	Number of participants (200)	Total
Social	Security	77	
	Preservation	57	
	Cultural heritage	188	
	Comfort	45	
	Outside space	30	
	Sitting under trees to cool off from the sun and chat	49	
	Privacy	32	
	Communal living	109	
	Modern	11	598
Economic	Cost	187	
	Material availability	120	
	Quick to build	86	
	Easy to repair	76	
	Easy to build	122	

	Access to farm land	98	698
Environmental	Cool interiors	189	
	Shape conforms to natural environment	89	
	Natural appearance	62	
	Freshness	56	396

Economic Score 1	Social Score 2	Environmental Score 3

4.18 Normalization of criteria values

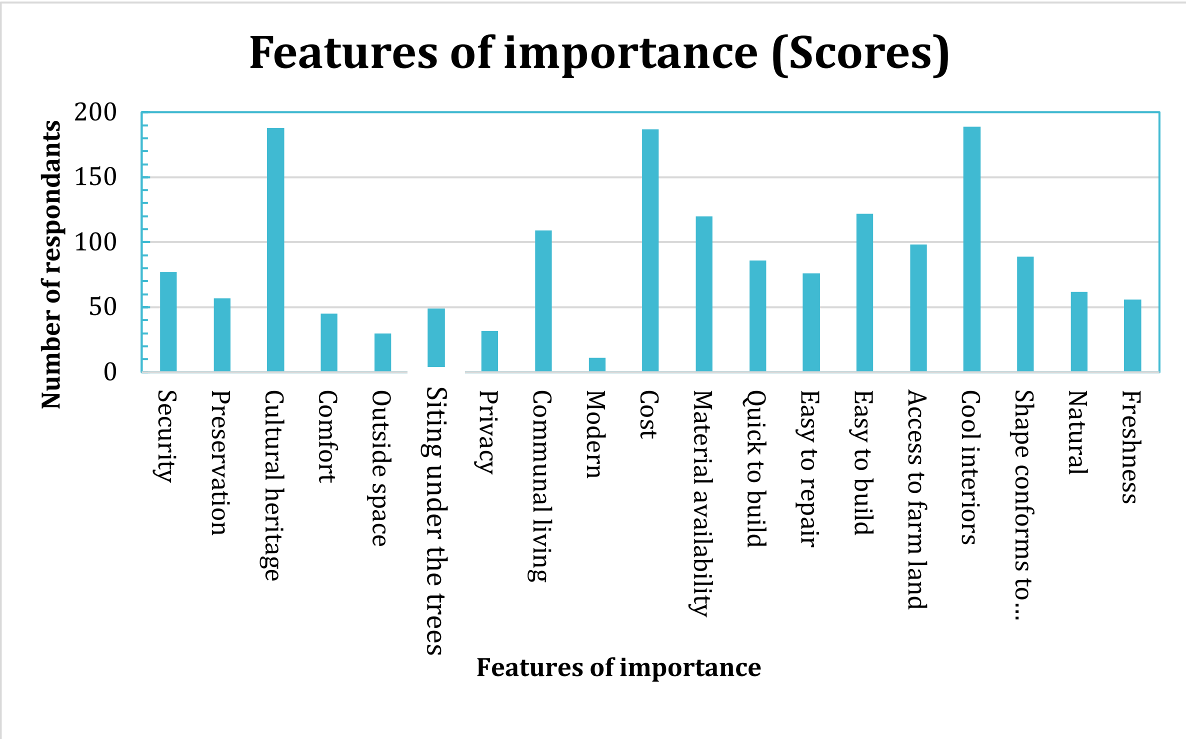


Figure 4.44. Features of importance for adapting the hut in Kanshio community.

Normalization of the criteria was conducted to avoid the influence of data being skewed. The initial measured values of the criteria are converted to non-dimensional comparative values remaining unchanged (Fig. 4.62).

- **Step 5**

4.19 Stakeholders' focus group discussion on weighting of indicators

4.19.1 *Outranking methods (risk assessment)*

This method identifies the dominance of one option over others against the different criteria. Instead of using numerical values, it uses descriptive information through the combination of information for each criterion for each option in an attempt to identify a clear narrative that establishes dominance of one option over others. It is similar to the method used by Kaiser *et al.* (2005). A simplified representation of what was most important to respondents in the focus group is shown above with numbers on pillars to show the number of people who thought those aspects of the hut were important (Figure 4.45). A further summary into classes of importance is depicted below under economic, social and environmental criteria.

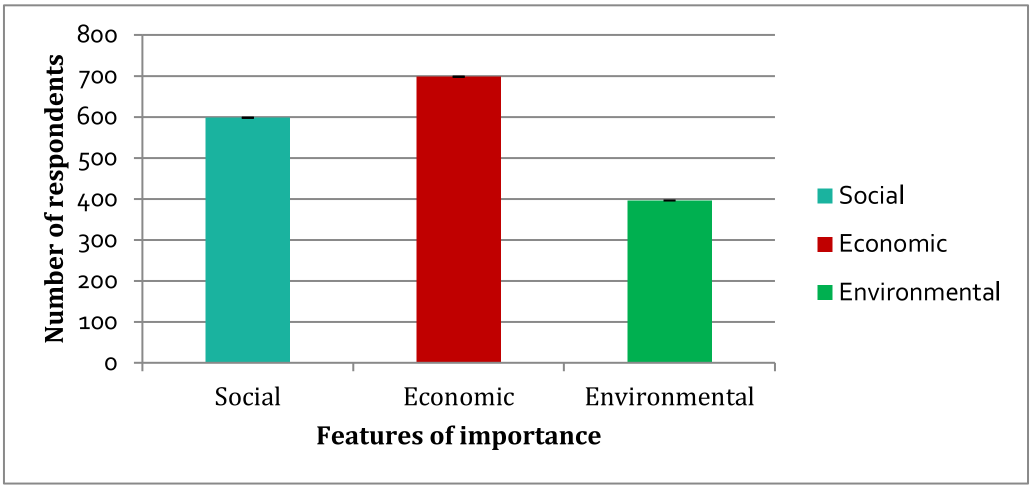


Figure 4.45. Categorization of features of significance.

Under economic reasons, cost was the main concern with 187 respondents of 200 stating influenced their building strategy. Percentage representation of all three barriers to adaptation are shown in Figure 4.46.

- **Step 6**

4.20 Objectives and alternative solutions

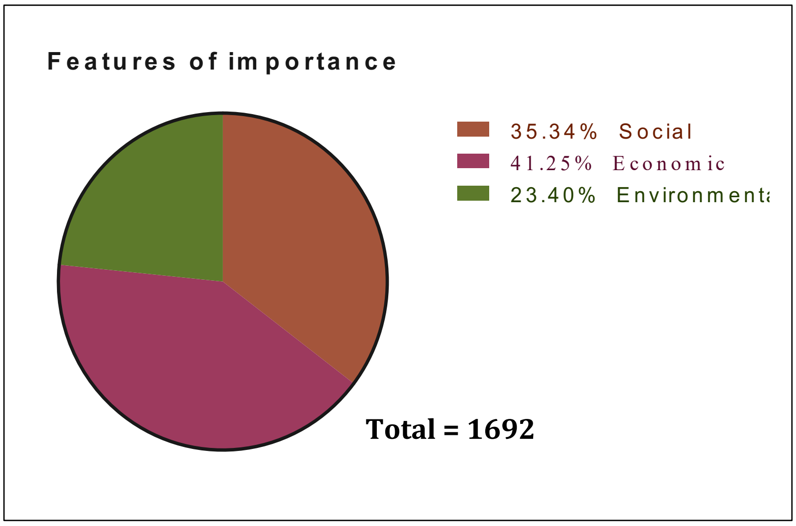


Figure 4.46. Summary of features of importance.

Figure 4.47 summarizes aspects of adaptation criteria to be considered. From a total of 1692 responses, the chart shows 41.25% in relation to economic reasons there has been no modification of the *Tiv* hut. It shows a breakdown of the reasons, especially relating to cost. This means that in adapting to the hut, economic impact has to be considered as a priority (e.g. cost, material availability).

The second important aspect for stakeholders was social factors. It was often asserted that typically to the present design of the hut had been a heritage and therefore part of the culture, specifically communal living. Some 35% of responses suggested that it was highly important to keep the style of the building and maintain what they considered as part of their identity. Some 23% of responses suggested that environmental factors were responsible for their building strategy. This includes comfort, natural feel of the building and shape of the building resembling the trees that hang over them. This information forms the basis for the adapted model in the case study area.

- **Steps 7 and 8:**

4.21 Monitoring and examination of results

This step analyses the results of temperature data of the model against the existing unmodified hut. The results of the MCA, used to create a list of options prioritized according to the criteria and preferences identified, are critically examined. The numerical weights in % are used, to derive the final score for each option. Based on weights assigned to each criterion, MCA methods resulted in a prioritized list of multiple options. Two-years of observation data are used for comparison of the model versus an existing unmodified hut (Table 4.27).

Table 4.27. Temperature readings for outside, inside unmodified and controlled hut

Unit °C	2016 Monthly	2017 Monthly	2016 Inside	2017 Inside	2016	2017

			Existing	Existing	Inside Adapted	Inside Adapted
January	33.9	34.6	32.6	33.5	28.8	28.2
February	35.8	36.7	34.3	35.6	29.6	29.8
March	37.7	36.9	36.3	35.0	30.2	29.1
April	36.6	35.1	35.2	34.0	29.1	28.7
May	32.1	32.5	31.2	31.6	27.6	27.4
June	30.8	31.2	29.2	30.2	26.7	26.5
July	30.1	29.9	29.0	29.0	25.6	25.3
August	29.9	29.8	28.7	28.7	22.1	24.4
September	30.4	30.6	29.2	28.8	26.1	26.3
October	31.8	31.7	30.1	30.4	27.1	26.4
November	34.3	33.4	33.1	32.1	27.8	28.5
December	34.3	34.1	33.2	33.2	28.1	27.3

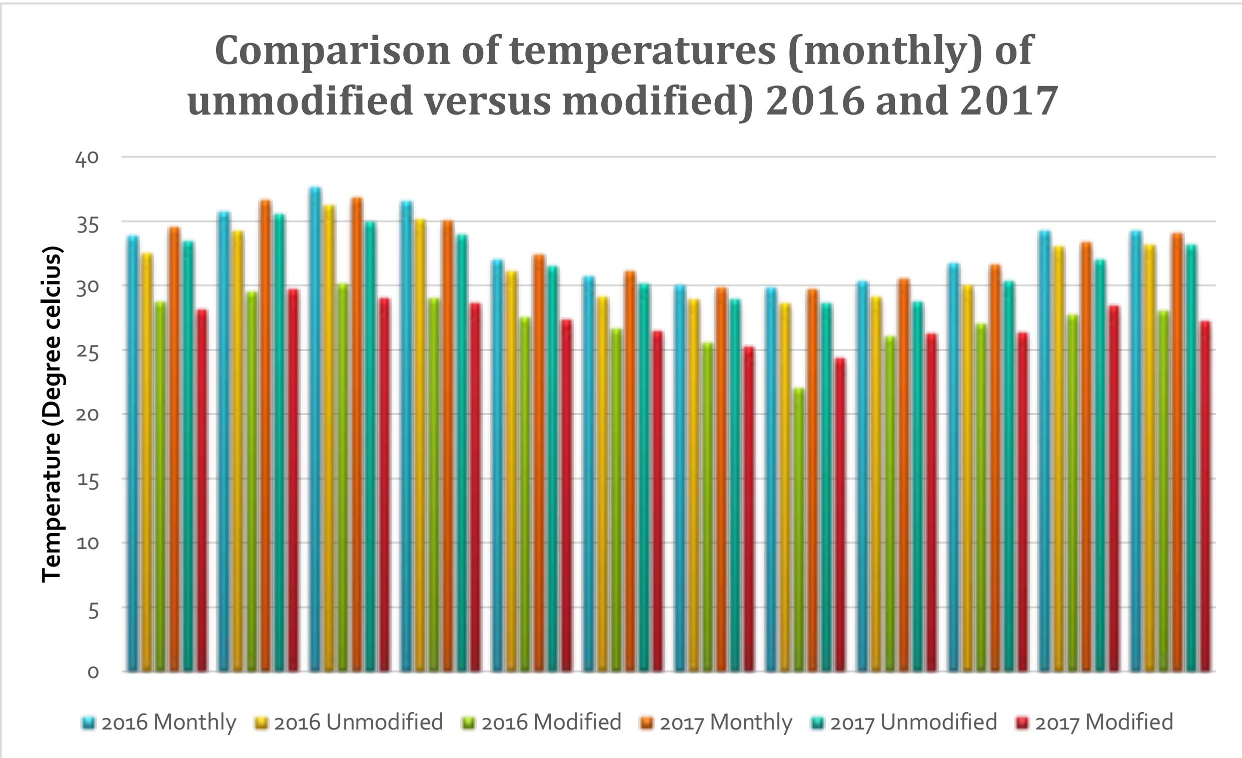


Figure 4.47. Temperature comparison of outdoor, indoor unmodified hut versus controlled project hut.

There were strong temperature differences between outside, inside the unmodified hut and inside the adapted model (Table 4.27, Figure 4.47). There were few significant differences between the outside and inside temperatures for the unmodified house. The case was different for the adapted hut. The Model hut typically remained within the average comfortable indoor temperature of 25-29^{0}C. To statistically analyse their difference, a two-way ANOVA test was carried out.

Table 4.28 show the ANOVA of the two factors. Each item in the model was tested for its ability to account for variation on the dependent variables, in which sample size, degrees of freedom, (DF) is calculated as (sample size -1), while the ratio of mean square deviation is given as the F statistic. The P level for each for each term is $P < 0.05$ indicating statistically significant variations between the outside, inside unmodified and controlled project temperatures.

4.22 Analysis of Variance (ANOVA) for 2016 temperature (outside, inside unmodified and control project)

Table 4.28. Analysis of Variance (ANOVA) for temperature (outside, inside unmodified and control project)

ANOVA: Two-Factor with Replication

SUMMARY	Unmodified	Controlled	Total
January			
Count	3	3	6
Sum	103.2	88.6	191.8
Mean	34.4	29.53	31.966
Variance	3.43	0.493	8.67
April			
Count	3	3	6
Sum	95.6	83.4	179
Mean	31.866	27.8	29.833
Variance	9.33	1.47	9.283
July			
Count	3	3	6
Sum	86.9	73.8	160.7
Mean	28.967	24.6	26.783
Variance	0.063	4.75	7.647
October			
Count	3	3	6
Sum	96.4	83	179.4
Mean	32.133	27.667	29.9
Variance	3.103	0.263	7.332
Total			
Count	12	12	
Sum	382.1	328.8	
Mean	31.842	27.4	
Variance	6.959	4.711	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	82.064	3	27.355	9.554	0.07	3.238
Columns	118.370	1	118.374	41.341	8.33	4.494
Interaction	0.491	3	0.164	0.0572	0.98	3.238
Within	45.813	16	2.863			
Total	246.736	23				

4.23 Cost of adaptation versus unmodified

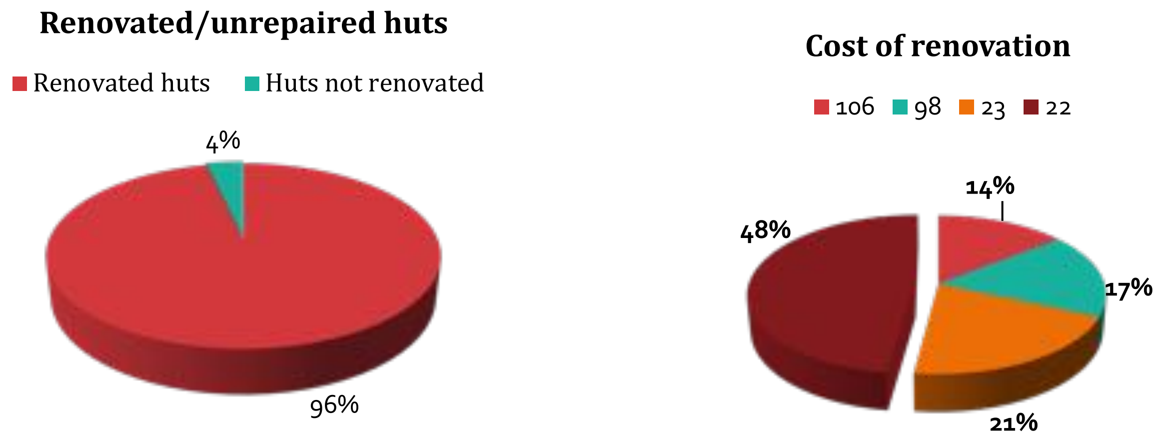


Figure 4.48. Cost of adaptation versus unmodified.

To calculate the cost of the case study and control hut (a summary of modified hut at 96% and 4% unrepaired hut is considered). Frequency of their repair and cost are summarized. Cost of repair and frequency are summarized in Table 4.29.

Table 4.29. Average cost of repair

Number of respond-ents	Frequency of repair	Average cost of repair ($)	Average cost of building ($)	Estimated total range of cost ($)	Estimated cost of building (median) ($)	Total spending on building in 2 years ($)
130	Once a year	15-25	86-112	101-137	119	238
58	Every two years	15-25	86-112	101-137	119	238
46	Every four years	25-40	86-112	111-152	132	264
16	No repairs	0	86-112	86-112	99	198

- ✓ Estimated cost of yearly repair at ~$15-25.
- ✓ Estimated cost of repair for every two years in the second year is $30-50.
- ✓ Estimated cost of repair for every four years in the fourth year is $15-25.
- ✓ 130 respondents renovated their houses every year. In the fourth year, they would have spent $30-50, mean $40.

In addition to their initial building cost, the average cost of renovation is \$60-100. The average cost of building a hut is \$86-112 (cost of unmodified hut = 80 + 92 = \$172).

The cost of a building is the total lifespan cost of that building, comprising of the initial costs of the cost of running and maintaining the building. The cost of maintenance for the unmodified hut and running it is derived through the questionnaires, as well as the frequency of maintenance. Difference in costs between people who renovated and people who did not, were significantly different (p <0.001).

Table 4.29. Test for significance in change of renovation frequency

	Number of respondents	Frequency of repair	Average cost of repair	Average cost of building		
	130	Once a year	15-25	86-112		
	58	Every two years	15-25	86-112		
	46	Every four years	15-25	86-112		
	16	No repairs	0	86-112		
Chi square Goodness of fit Test						
Category	Frequency of repair	Observed	Expected			
1	Once a year	130	62.5			
2	Every two years	58	62.5			
3	Every four years	46	62.5			
4	No repairs	16	62.5			
		250	250			
	Chi-square goodness of fit test					
	Chi-square	112.2				
	DF	3				
	P value (two-tailed)	<0.0001				
	P value summary	****				
	Is discrepancy significant (P < 0.05)?	Yes				
	Outcome	Expected #	Observed #	Expected %	Observed %	
	Once a year	62.5	130	25	52	
	Every two years	62.5	58	25	23.2	
	Every four years	62.5	46	25	18.4	
	No repairs	62.5	16	25	6.4	

	Chi-square goodness of fit test			
	Chi-square	112.2		
	DF	3		
	P value (two-tailed)	0.001	***Highly significant***	
	P value summary			

4.23.1 *Cost of building the modelled hut*

Table 4.30. Material cost of building the modelled hut

Material	Initial Cost (₦/) (Control project)	$	Initial cost Naira (Unmodified)	$	Cost of Mainten-ance ($)	Cost of maintenance per year
Clay vs Mud	13,000	36	6000	17	0	2800
Transporting Clay	6000	17	3000	8	0	-
Bamboo	4000	11	3000	8	0	0
Cement	4350	12	0	-	0	-
Aggregates	450	1.5	0	-	0	-
Cow dung	200	0.55	0	-	0	-
Gravel	1500	4	0	-	0	-
Burnt bricks	1950	5	0	-	0	1230
Door frame	1500	4	900	2.5	0	0
Door	4000	11	3000	8	0	0
Brick layer	1080	3	1000	2.7	N/A	-
Brick laying	2500	7	1500	4	0	-
Thatch	20,000	55	12000	33	0	8000
Thatching cost	8000	22	5000	14	0	2000
Builders fee	12,500	35	4000	11	0	900
Louvers	2000	5	0	0	0	-
Window mosquito net	1000	3	1000	0.15		-
Total	₦84,030	$232.5	40,400	$108.34	0	17

Total cost of controlled Project = $250. Size of controlled project hut = 4.6 m.

Table 4.31. Comparison of cost of prototype versus case study

Frequency of repairs	Number of respondents	Total Cost of Unmodified ($) per 2 years	Cost of Modified ($)
Once a year	130	238	232.5
Every two years	58	238	232.5
Every four years	46	264	232.5

No repairs	16	198	232.5

Cost of unmodified hut is compared with the costs of the control project using ANOVA.

Table 4.32. Cost of construction

ANOVA: Two factor with replication

SUMMARY	Total cost of controlled vs unmodified					
once a year						
Count	2	2	4			
Sum	476	465	941			
Mean	238	232.5	235.25			
Variance	0	0	10.08333			
Every four Years						
Count	2	2	4			
Sum	462	465	927			
Mean	231	232.5	231.75			
Variance	2178	0	726.75			
Total						
Count	4	4				
Sum	938	930				
Mean	234.5	232.5				
Variance	742.3333	0				
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	24.5	1	24.5	0.044995	0.842383	7.708647
Columns	8	1	8	0.014692	0.909368	7.708647
Interaction	24.5	1	24.5	0.044995	0.842383	7.708647
Within	2178	4	544.5			
Total	2235	7				

Results show that there is no significant difference in the cost of building the control hut and the existing hut.

CHAPTER 5 : DISCUSSION

5.0 Introduction

While there have been many attempts by environmental organizations to mitigate and adapt to CC, adaptation has created fundamental issues. For instance, Yau and Hasbi (2013) suggested that most buildings in Europe are designed to utilize natural ventilation as opposed to mechanical ventilation, such as central air conditioning units and openings, as a means of reducing environmental impacts and operating costs. They further suggested that this situation is gradually changing as heat consumption, ventilation and air conditioning have been increasing throughout Europe. Researchers, such as Brooks *et al.* (2009), Grothmann and Patt (2005), Kelly and Adger (2000), Smit and Wandel (2005), Ziervogel *et al.* (2016) and Singh *et al.* (2017) all agree that proactively preparing for expected local CC impacts can increase a community's capacity to adapt. Adaptation provides added preparation time to raise funds and implement tasks to increase the adaptive capacity of communities. Although research stating these facts is readily available, it is also generalized.

Adaptation to CC is an important issue; however, little attention has been paid to the consequences of adaptation policies and practises for sustainability. On an international level, adaptation has gained much recognition, more so on a theoretical basis. Locally, however, it is observed that not every adaptation to CC is a good one. This has drawn attention to the need for sustainable adaptation plans and procedures that add to community fairness and environmental integrity. This local approach also enables a more involved role for the public, which has been limited in national policy-making. Since the impacts and causes of CC are distributed unevenly, solutions need to be found that are contextually significant (IPCC, 2001). Burnett *et al.* (2009) agreed that climate records from the tropics are under-represented in many studies, in particular records from Africa. Developing countries especially have very different distinct conditions and the specific impacts of CC on a country are influenced by the climate and geographical, social, cultural, economic and political situations. For this reason, countries require various adaptation measures, depending on their distinct circumstances.

This study considered four standard principles to aid responses to CC and demonstrate the importance of the sustainable adaptation ideas through the case study.

1. Recognizing that people are vulnerable.
2. Admitting that contradictory standards and benefits affect adaptation outcomes.
3. Integrating local knowledge and culture into adaptation responses and prioritization.

4. Considering potential feedback between local and global processes.

For these outlines to be effectively observed there is a need to measure and estimate likely impacts. These principles are based on the Fifth IPCC Report (Huq *et al.,* 2014).

5.1 Climate conditions in the case study area

Results from annual income indicate that agriculture is the main source of income in the case of the community (Figure 4.6). In the rural areas of tropical regions such as Benue State (with the Slogan '*Food Basket of the Nation*') where agricultural activities account for as much as 70% of incomes, CC is bound to significantly impact on the economy. The Nation's (2013) analysis shows that 34% of respondents are farmers and 17% business men, while 27% are civil servants (Figure 4.5). All three classes are agriculture based. Thus, 78% are engaged in the sector.

5.1.1 *Temperature variability*

Authors such as Sigh *et al.* (2014), Gosling *et al.* (2014) and Wilson *et al.* (2019) indicated that extreme temperatures will become more common in the future. The extremes of these temperatures make climate impacts difficult to cope with. Harisi *et al.* (2011), discussed climate impacts on tropical biodiversity as a subject of active debate and sugested that CC is having increased effects on biodiversity. Their research is congruent with studies by Sedjo and Roger (2007) which focused on temperate environments, with rare mention of changes in the tropics (Laurance *et al.,* 2011; Wormworth and Sekercioglu 2011 in Harisi *et al.,* 2011). Rosenzweig *et al.* (2008) stated that "*of the 30,000 studies reviewed for the IPCC 2007 Report, less than 1% were from the tropics*". The lack of research on climate impacts on tropical climates combined with the perception of a small overall degree of projected temperature and rainfall changes has worsened the situation (Harisi *et al.,* 2011). The lack of research in the tropics continues to generate difficulties, as tropical dwellers often have little information on how to cope with the changes. Decision-makers have insufficient information on what steps to take in response to CC. This is why research to gather data in rural and deprived settlements, such as the case study is imperative. Figure 4.29 shows a contrasting report of rising temperatures in the case study. Results show maximum temperatures have consistently decreased with minimum temperatures increasing. Figure 4.30 shows a mean temperature decrease from 39.5°C in 1991 to 34.6°C in 1994. Figure 4.30 also shows a maximum temperature of 38.9°C decreasing to 34.5°C for the hot season from 1994-1999. A close observation of the hottest month for the entire 28 years of historic and primary data (March) from Figures 4.23–4.27 shows a steady decrease in temperature for every five years. Temperature records from 1990-1994 show a decrease from 39.5°C to 38.9°C (Figure 4.23). From 1995-1999, there was a further decrease to 37.9 > 37.6 >37.5°C every five years. The highests maximum temperature was measured in 1998 at 38.9°C. A weak correlation exists between minimum and maximum temperature series. A mean temperature trend for Makurdi is also calculated by combining all the available raw data and comparing maximum and minimum temperature series. The procedure was repeated on mean temperatures.

5.1.1 *Effect of rainfall on temperature*

This study shows that maximum temperature was low in the July, August and September, which are the months with the highest rainfall. This rainfall tends to reduce the daytime (maximum) temperatures, while cloud cover reduces the intensity of solar radiation reaching the earth's surface. The maximum temperature was also observed to be high in February, March and April. These months are in the pre-monsoon seasons, in which the effects of the cool tropical continental (cT) air-mass have weakened, leaving the atmosphere dry and warm (Orisakwe *et al.,* 2017). These months (February, March and April) witnessed the second highest temperatures (38.5°C) for the period 1990-1994. This shows a direct relationship between rainfall and temperature. Hot tropical climates will experience higher temperatures with decreased rainfall.

5.2 Impact of rain on building structures

The amount, path and force of rainfall on a building will affect features of a building design, such as roof shape, flashings against the wall, storm water drainage, rainwater collection and covering type. Obtaining rainfall data for the region was therefore an important part of the preliminary design brief. Rainfall intensity varies throughout the year and from season to season, so average rainfall figures can be misleading. Some parts of the country experience intense rains that can be substantially higher than the average would suggest. Buildings should, therefore, be designed to cope with the maximum expected rainfall. Some 47% of respondents attributed the cause of building damage to rain (Figure 4.14). Meanwhile, 45% reported rain as the most impactful weather parameter on their hut. It was further ascertained that the foundation was a main focus of repair due to rain.

A common practise in the case study area is to use brick blocks and attempt to stop water penetration and accumulation around the foundation by putting them round the hut (Figure 5.1). This practise is assumed ineffective based on the number of repairs to foundation walls; 67% respondents had undertaken repairs.

Similar research was carried out by Jayamaha *et al.* (1997), who experimented on a 40 mm thick concrete building wall, carrying out one test in the rain and another in dry weather. In the rain simulation tests, the water spray arrangement was used to simulate rain conditions by spraying water on the wall surface. Rain replication tests were carried out for both continuous and intermittent rain patterns selected from representative patterns in Singapore. The results showed a significant reduction in heat flow due to rain effects.

The size decrease for the brick specimen lasts much longer than for the concrete wall, since it is more permeable and thicker and therefore able to absorb more water during rain. During the dry period after rain, the heat flows for the brick wall are increased. This verifies the relationship between temperature and rain, reinforcing their importance in building design and style. This research reinforced foundation walls by using burnt bricks, concrete binding and hard aggregate to minimize water penetration (Figure 5.1).

Figure 5.1. Reinforced foundation wall, (author's photograph, 2015).

One of the issues surrounding CC lies in the uniqueness of local CC. Foster (2001) stated that local climates are likely to be affected by local events, such as deforestation, material choice and methods. While local changes may be much stronger than global changes at a given site, generalizing local changes is problematic. Even within neighbouring areas, CC impacts and prioritization significantly differ (Figure 4.32). In this study, it was observed that one of the huts which had no repairs within two years was located under trees with shrubs at the base of the structure. It received minimal water-logging at the base and reduced the force of rain on the roof due to being shielded from the rain by trees. Franchito *et al.* (2011) investigated the relative roles of future GHG concentration and future fluctuations in land cover due to tropical deforestation. They suggested that CC at the regional level due to large land cover changes may be more than that owing to GHG only. Conversely, the impact of GHG concentrations globally appears to take over the impact of land cover change (Franchito *et al.,* 2011). It may be then resolved that the most short-term studies have focused on absence and the difficulty of separating numerous factors of change, such as habitat loss, disturbing species and CC (Brook *et al.,* 2008 in Harisi *et al.,* 2011). Considering vulnerability in building energy demand, climate adaptation can be implemented by increasing building adaptive capacity.

The University of Miami (2013) reiterated the global dimensions of the impact of CC by pointing out that dust clouds from the Sahara Desert sometimes travel thousands of kilometres across the Atlantic Ocean. The study goes on to point out that in a recent study at the University of Houston and Arizona State University, researchers found that the average air concentrations of inhalable particles more than doubled during a major Saharan dust intrusion in Houston, Texas. This stresses that local impacts of CC often have global effects and that although impact needs to be tackled locally, ultimately their effects have global dimensions. The importance of community adaptation strategies, such as this research, should therefore not be undermined, as its effects can bring global outcomes. In Benue, >40% of the population live in huts. If the way they live is improved and lives are consciously improved and people live in a sustainable way, over time the effects will be spread nationally and, subsequently, globally.

Building performance is based on a set of facts and not just promises (Woods, 2008). If the promises are achieved and verified through measurement, advantageous consequences will result, and risks will be minimized. However, if the promises are not realized, adverse consequences are likely to lead to additional risks to occupants, building owners, designers and contractors; and to the larger interests of national security and CC.

5.2.1 Source of lighting

The lack of literature specifically for Benue State emphasizes the lack of research covering communities in the case study area. Another key concern in the case study area was the use of kerosene lamps as a source of day and night lights. Figure 5.2 shows how dark it is in the hut during the day without a source of light. Although there is little literature on the impact of kerosene lamps and generators in respect to CC, Tedsen (2013) reported the use of kerosene lamps, commonly used in developing countries, as emitting the greenhouse gas (GHG) CO_2 in the same way as other types of fossil fuel combustion. Because lamps additionally emit black C, their contribution to CC is substantially increased. Some 54% of respondents used kerosene lamps as a source of day and night lighting. In the day, it was typically because the overhang covered the windows and prevented daylight penetration.

Figure 5.2. Window size and position in relation to lighting, (source: author's photograph, 2015).

Figure 5.2 shows two pictures, with one taken with a camera flash shows some clarity in the room, while the second without a flash at 1400 shows the difference between having a source of light and no lighting. To address the issue of blocking sun-light, water splashing and heat transfer, inexpensive controllable wooden louvres are fixed (Figure 5.3). This helps occupants control the angles and amount of light penetration.

Figure 5.3. Controllable louvres on the control project, (source: author's photograph, 2017).

Louvres will reduce and probably stop the burning of fuel for lighting during the day by 54% according to respondents**.** Black C is the result of incomplete combustion of fossil fuels, biofuels and biomass. Black C elements absorb daylight and heat the atmosphere, increasing radiative forcing and contributing to CC (Tedsen, 2013). Tedson (2013) reported black C as a chief climate warmer, second only to CO_2. Nicholas *et al.* (2012) reported 500 million households still use fuels, particularly kerosene, for lighting. Tedson (2013) stated that Nigeria alone installed ~43.6 million lamps in 2013.

Nigeria ranges from being a medium to high producer of pollutants from kerosene lamps (Figure 1.3). New research has shown that kerosene lamps are significant sources of atmospheric black carbon and emit 20 times more than previous estimates, with 7-9% of fuel burned converted into black C particles (Nicholas *et al.,* 2012; Collins, 2014; Muyanja *et al.,* 2017). While some sources of black carbon emit other non-black particles (organic carbon) that may have an offsetting cooling effect, kerosene lamps emit almost entirely black C and CO_2, both of which cause warming. At least 270,000 tonnes of black carbon per year is estimated to be emitted from kerosene lamps worldwide, having a climate warming equivalent of ~240 m t of CO_2 (Nicholas *et al.,* 2012).

For sustainable development pathways to be achievable, fundamental societal transformations are required. These transformations are often behavioural. Many challenges are involved in realizing such change; sustainable adaptation practises have the potential to address some of the inadequacies of conservative social and economic progress pathways.

Although there are many adaptation policies and practises which can potentially reduce the negative impacts of CC, little attention has been paid to their consequences on the socio-cultural values of stakeholders. For instance, results show that different communities will have different priorities to adaptation. In the case of this research, the most important aspect of adaptation is cost (Figure 4.46). However, in the Canadian Western Arctic community what was most important considering building adaptation stages was the preservation of culture (Berkes and Jolly, 2001). Considering the average monthly income of these two countries and their economic and social environments, it is anticipated that economic factors will impact more in Nigeria, which is a developing nation.

In some instances, what may seem to be an effective adaptation option to CC may undermine the social, economic and environmental purposes associated with sustainable development. Policies that make sense from one perspective may at the same time reduce the resource access of other groups. Similarly, a willingness to reduce climate risk through specific knowledge may sometimes lead to the neglect of other environmental concerns (Næss *et al.,* 2005; Eriksen and O'Brien, 2007; Eriksen and Lind, 2009). For example, the case study window size remained small to minimize sunlight penetration, thus, heat exchange but also stopped daylight penetration leading to the use of kerosene lamps as a source of light. The controlled project widened windows and applied louvres to minimize sunlight at different angles without completely preventing light penetration, which leads to heat gain.

The importance of this principle is illustrated by the case of poor rural communities in Makurdi, (Benue State Capital). There are several factors that stress and generate vulnerability in these areas. It is therefore important to tackle socio-economic dimensions alongside infrastructure to minimize climate impacts. In Nigeria, where poverty is especially high in rural areas, people are particularly drawn to coping mechanisms. These are more likely to emerge at the level of the individual and the household and thus, at smaller spatial scales (Berkes and Jolly, 2001).

Many of dwellers in the case study area are farmers (34%), levels of education are low and very few are engaged in the skilled sector (27%). Most workers are builders, farmers and traders. Household sizes are large; ~80% of the households have over four people. Some 59% have an income of <$530 US dollars per annum (Figure 4.6). Although houses are not old, collected data show that they have mostly needed maintenance and repair (>50% are <10 years old). Many are constructed from materials that do not withstand rainstorms and flooding (Figure 4.12). The key conditions generating vulnerability in the case study area include poverty, poor economy and lack of awareness of adaptation measures and social injustice.

Several socio-environmental changes produce the described conditions. These include the marginalization of poor communities in terms of infrastructure, services and opportunities to gain additional income. Another factor is physical development on environmentally sensitive lands such as wetlands, slopes and floodplains, that hasten environmental degradation and increase flood risk (Olorunfemi and Raheem, 2007; Olorunfemi, 2008; Mehrotra *et al.,* 2009; Gbadegesin *et al.,* 2010) (Figures 5.5, 5.6). Extensive damage to properties and livelihoods contributes to the endemic poverty in most of Benue State.

Figure 5.4. Submerged hut in Benue State, (source: Tukur S., 2012).

Figure 5.5. Collapsed hut in Makurdi due to flooding (source: Daga, 2015).

For instance, increasingly frequent and severe floods have damaged local communities and market places, disrupted trading and washed away crops. Traders, artisans, children and women farmers are among the most vulnerable groups. Very often responses to these events are reactive, as there is no preparation in place. Drainage is often absent. Thus, buildings imbibe water and subsequently collapse.

5.2.2 Politics, transparency and emergency responses

Reports such as the Sahara Newspaper (2016) indicate fraud in Benue State flood camps. They report an instance where some buses conveying paid but unaffected residents of Makurdi, arrive to top up the Camp's capacity, with the motive of giving visitors an impression of a camp in crisis mode, teeming with people and needing more supplies. These fraudulent acts are common in areas of poverty. There is therefore a need to create models that provide more permanent solutions to the issue of CC than settling for reactive responses.

5.3 The need for climate models

Developing countries are the most distressed because of climate inconsistency and they have a huge lack of basic infrastructure to safeguard their settlements. In addition, funds and technical capability are very limited. Hence, adaptation actions to guard towns need to be planned and prioritized cautiously to reduce exposure and the risk. A framework for prioritization of adaptation actions is missing in decision-making. A framework which could immensely assist in adaptation planning processes.

The Fourth Assessment Report of the IPCC (2007) reviewed some likely impacts due to global warming, on the assumption that adaptation in 2030 will need to anticipate future warming. The IPCC (2014) reported projected temperature rise between 0.38-4.8^{0}C by the end of the Century compared to the beginning of the last 20th Century, with both extremes having very different outcomes. One emerging aspect is the significant magnitude of impacts that could occur even within the next few decades and the scale of costs that could be expected if adaptation is not fully successful in avoiding them. In rules of management, it is popular to hear that the phrase *"we cannot manage what we cannot measure"*. This research has investigated the current state of adaptation to CC in a community called *Kanshio.* The aim was to investigate how the community was dealing with CC impacts.

5.4 Supportive networks

It is important to develop measures that contribute to sustainable development while creating adaptation responses. To do this, it is necessary to address the factors that create vulnerability. Some of these measures need to include an understanding of the importance placed on adaptation aspects. This research shows that in adaptation, it is important to consider the economic state of the community and the social and cultural importance placed on built structures.

For example, support from friends, relatives and personal savings explain how many disaster victims cope with the immediate impacts in a community. Up to 72% of huts were reported to be built by family and friends. Sustainable adaptation measures must be sensitive to the need to sustain such support networks. However, measures need to address the vulnerability context in the long-term by complementing household mechanisms and addressing some of the structural processes. This could be achieved, for instance, by facilitating livelihood diversification and formal support systems that could relieve stresses on social networks during disasters. This first principle of sustainable adaptation involves broadening responses to recognize and where possible, directly address, the context in which CC is experienced. This context includes stressors, such as the marginalization of urban dwellers in terms of infrastructure, services and income opportunities, as well as physical developments that threaten environmental integrity and exacerbate flood risk.

5.5 Features of importance

The research acknowledged that different values and interests affect adaptation outcomes. Respondents had multiple and potentially conflicting criteria to consider before making decisions. In the investigated community, social, economic and environmental criteria were considered. Building a defence against rising storm surges and more comfortable indoor temperatures were identified as important. However, cost is rated an issue of high concern with social and cultural concerns ranking closely as a second concern and finally environmental concerns.

Values and interests play an important yet rarely discussed role in CC responses and they influence the adaptation strategies that are prioritized by different groups (O'Brien, 2009). Recognizing potential value conflicts can help to identify how adaptation responses taken by one group may affect the vulnerability of other groups. Strong vested interests within particular adaptation strategies may act as an obstruction to sustainable types of adaptation. Results show that the concerns of most respondents are based on ignorance due to lack of information on alternatives strategies.

Climate models portray the general existing scenario of CC occurrence and provide estimates for the likely consequences of changed future scenarios. However, adaptation options are far more specific at the local level, as the same city with the same temperature and rainfall may still need to adapt differently in each specific community. This is usually based on factors such as topography, material availability, transportation of materials and employment. Global strategies for adaptation are poor at providing information about local changes. In recent years, there has been an increasing realization that indigenous groups are a valuable source for these data. Indigenous people are both keen observers of CC and are actively trying to adapt to changing conditions. In some instances, people can draw on already existing mechanisms for coping with short-term adverse climatic conditions. Some of these responses may be traditionally included in their normal subsistence activities, while others may be acute responses, used only in the case of critical weather conditions (Stott and Kettleborough, 2002). Studying successful cases, like those detailed in Chapter 2, enables the transfer of useful information on adaption methods.

5.6 Government's responsibility for barriers to adaptation

Although the general opinion on adaptation options are placed on the government, the question to consider is the government's economic ability to adapt. Where the government has the economic ability, the next concern will be the availability of information and measurements on the scale of adaptation. Despite the importance of identifying opportunities for adaptation, there are few studies on how local government can facilitate adaptation. Kumar and Geneletti (2008), for example, highlighted the limited integration of CC issues into spatial forecasting at the city scale in India. They discussed several hindrances, including lack of initiative by local government. However, examples are starting to emerge of how integrating community-based adaptation at the city scale can have extensive transformative potential for governance. In the case of Maputo (Mozambique) residents of a low-income settlement who suffer frequent flooding were clearly involved in shaping the city's adaptation plan and were supported to develop their own unique plan.

5.6.1 Community plan for climate change adaptation

Although many studies acknowledge the importance of local government in adaptation successes, practical community adaptation studies, such as this one, are scarce. Local government can be an important implementer of climate adaptation, because of its capability to plan and succeed at the local scale and link to rural and state government. Finding ways for local government's role to be reinforced to include the assistance of joint and multilevel adaptation preparation is, consequently, a priority.

5.7 Barriers to climate change adaptation at the local/community level

Generally, people have more to benefit if they act to solve local adaptation problems and also more to lose if they fail to act. As the number of actors increases, the impact of individual action to adapt to collective problems decreases. Thus, strategies to motivate public action to tackle CC need to focus on the local level, where individual fears, dependence and effectiveness are highest. However, there are constraints to these actions.

This research found that one of the main constrain to CC adaptation at the local level, after cost, is people's need to preserve their cultural heritage/identity. In Nigeria there are over 300 languages. Thus, cultural heritage varies very widely. It is therefore important to reflect and preserve cultural identity in adaptation procedures.

5.7.1 *Cultural heritage management and preservation*

It is evident from the focus group discussions that the occupants of the case study community considered the preservation of their cultural heritage as critically important. This is therefore seen as a barrier capable of impeding adaptation strategies that clash with their identity. Understanding barriers can therefore increase the success of adaptation responses to existing and possible imminent CC, prioritization of adaptation strategies and maximizing decision-making efforts. Barriers to cultural heritage adaptation or historic preservation worldwide are poorly understood (Fatori´c and Seekamp, 2017; Phillips, 2015).

Understanding the hurdles that are likely to stop the conservation of traditional identity is of vital significance; as it cultivates results that aid the preparation and management of susceptible cultural resources. Using the interview schedule, questionnaire and a focus group discussion, prompted the opinions of stakeholders across the case study community.

Ten officials in the Department of Environmental Management of the local authority responsible for decision-making in the study area were questioned. Thus, what were the greatest challenges facing cultural heritage policy and practises from CC impacts and what strategies and information is needed to overcome those challenges. Their responses were all very similar, as they noted that plans were ongoing on long-term policies to respond to climate impacts in the area. They also all acknowledged that there were only relief camps for affected individuals in the State. This confirms the lack of preparedness, with the government leaving the public to look after themselves. The round circle of reactive responses was surprising. This research is very important, as it gives proactive reactions as opposed to the reactive ones practised in the case study area.

5.7.2 *Technical barriers*

It is common-place in developed cities for weather hazard warnings to be issued to communities ahead of likely impacts. However, lack of technical skills for making decisions about adaptation is common in developing countries and especially poor communities. There are also limited procedures for gathering data. When coupled with CC uncertainty, this knowledge gap may obstruct adaptation.

5.7.3 *Social barriers*

Adaptation can arise from various factors, such as the perceptions, values and norms found within society. Sherren *et al.* (2016) found that cultural values, symbolism and place attachment were considerable barriers to adaptation planning in cultural landscapes. Limited motivation and unwillingness to act and conflicting perceptions about the practicality of adaptation and strategies have emerged as major factors constraining climate adaptation processes. The results from a focus group showed that this barrier was a concern for the community and is therefore important to note throughout adaptation stages. The *Tivs* are known for their hospitality and communal lifestyle. It is clear those outdoor activities were important and valued (Figure 4.36).

5.7.4 Financial barriers

Adaptation contexts are primarily related to the lack of funding, especially in poor communities. The earnings of residents show that typically the community is a low income one, which will first be concerned with food, clothing and basic shelter. Incorporating measures for adaptation will, therefore, be the least of their priorities, especially combined with unawareness and an absence of alternatives. Additionally, limited financial willingness by government to mobilize funding for research and new technologies pose a substantial barrier. Climate adaptation requires significant financial investments. However, the financial benefits of adapting cultural resources are often unclear, possibly due to conflicting planning time-scales. (Phillips, 2018).

Research in heritage preservation has largely been singular, identifying institutional, financial, technical or social barriers that hinder CC adaptation processes as individual issues. To enable more durable and efficient responses to the challenges that adaptation presents, there is a need to move beyond single-disciplinary assessments and identify inter-disciplinary barriers for climate adaptation of cultural heritage. Outside the heritage field, Eisenack *et al.* (2012) highlighted the importance of understanding how barriers are related to each other and how these may change over time. Similarly, Moser (2007) recognized the need for more empirical studies to explore the growing importance of barriers to adaptation. CC impacts on Africa's agricultural sector, especially decreased crop production, remains the main problem of income, as Africa is heavily reliant on agriculture (Bryan *et al.,* 2013).

5.8 The need to protect cultural heritage

Societies have long sought to guard their cultural heritage, for reasons ranging from education to historical research to the desire to reinforce a sense of identity. In times of war and conflict, cultural identity and cultural heritage become increasingly important. Major television channels all over the world carried the news of Islamic State's (ISIL) deliberate destruction of 28 historical religious buildings, cultural heritage and ancient historical artefacts in Iraq, Syria and Libya in June 2014 and February 2015, as headlines emphasized the importance of cultural preservation.

5.9 Consequences of modernization on cultural preservation

In addition to the mentioned barriers, modernization can also be a barrier to adaptation. People see modernization as progress and are sometimes pushed to build more modern houses, even when maintaining them will prove difficult and unsustainable. When people travel to foreign countries and return home, they often look down on their own way of life. Although this in itself is not bad, it comes with a cost and usually impacts on cultural heritage and identity. Focus group discussions indicate that 98% of dwellers are not willing to change their cultural identity in respect of buildings. This became an important decision in prioritizing adaptation strategies for this research and kept all features of the hut as traditional as possible.

5.10 Social intimidation

It is frivolous for poor people to live in housing of high architectural standards, which does not equal their needs and incomes (Gilbert and Guggler 1994, in Olutuah, 2009). The inability of architects to put housing problems into proper perspective is partly as a result of inadequate architectural education on housing matters. Perceived deficiencies can be traced to the prospectus of study they underwent. "*Problems cannot be properly stated unless the underlying issues are understood*" (Turner, 1976 in Olutuah, 2009).

CHAPTER 6 : CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

The evaluation and prioritization of adaptation options in 'Kanshio' community should reflect the preferences and values of the stakeholders, as well as local knowledge, based on social, economic and environmental considerations to increase sustainability.

6.2 Social considerations for adaptation

The results of the recreation of the control hut suggested that considering traditions of vernacular construction as a method for improving building energy performance is a useful endeavour and technical guidance can help improve performance. Although several vernacular settlements exist in the world, they all have their uniqueness and will need different approaches to adapt to CC. It is important to use structured method for designing climate adaptation policies based on the perceptions of adaptation pathways and analyses of physical option.

The approach results in the incorporation of options that permit change over time in response to how the future develops, what is learned about the system and changes in cultural preferences.

The approach is illustrated by building an adapted traditional hut of the '*Tivs'* called 'iyough Toho' meaning 'the house of grass.' Social factors of adaptation in the case study area are considered as follows:

1. The cultural values of the *Tivs* impact on their buildings.
2. These values dictate the circular shape of their buildings, because of their communal nature.
3. The hut shape creates a good view of the immediate environment. It also improves security in terms of vigilance from unforeseen incursions.
4. The size of the buildings is influenced by the status of the occupant/owner in the society.
5. Religious beliefs stress that the gods are happy with preserved nature.
6. Although social values are very important, results show that the dwellers are more concerned about the cost of improving the Tiv hut than the social reasons.

6.3 Environmental considerations of adaptation

1. Compatibility with relevant nature, such as climate, geology and topography.
2. The windows in the round huts are meant to maximize the thermal property of the thick clay walls.
3. The cylindrical buildings paradoxically have the same visual effect as the tall trees in the forest zones.
4. The surface of the clay wall blends with the natural look of the surrounding and eliminates harsh contrasts.

6.4 Economic considerations of adaptation

Multi-Criteria Analysis (MCA) process in facilitated the identification the range of cost-effective options to be analysed. They can also help shape the inclinations of the stakeholders part of the MCA process and determine the final outcomes of the process and are a useful means for providing structure to a formal decision-making process, because they make these preferences more transparent and clear, allow for the inclusion of evidence and science and leave room for the inclusion of local knowledge and stakeholder preferences. They allow for conversations and processes to begin, which will help in discussing problematic compromises between executing one adaptation option over another. In this case, hierarchy is from economic to social and finally environmental. The process and conversation amongst decision-makers and stakeholders in the focus group discussion were important as they provided a more practical approach to cost prioritization. Prioritization was based on resources, data needs, time and capacity. It allowed the use of different types of information and simplified complex problem. Some of the economic factors of adaptation considered are as follows:

1. Function of immediate natural environment in terms of form and style.
2. Availability of local building materials.
3. Cost is rated the highest reason for failure to adapt.
4. Walls are prone to cracks and surface wash after every dry and wet season.
5. There is 85% and 70% refurbishment of the walls and roof, respectively, every two years.

The average cost of refurbishment per household over two years ranges from $30-50. When this is added to the initial cost of building ($119) which ranges from $86-112, the adapted estimated total spending on the adapted hut is $6 in more than the 'control' hut $226. (Cost of adapted hut =$232).

6.5 Recommendations

The increasing emphasis on control, which goes beyond government to the multi-level structures and processes by which government and other actors make decisions and share power, is critical. While it is important to stress the need to recognize the complex political and social dimensions of decision-making processes on climate adaptation, measures need to be put in place.

A Theory of Negligence states that the purpose of tort "*is to generate rules of liability that if followed will bring about, at least approximately, the efficient cost-justified level of accidents and safety".* The welfare-based normative approach should be exclusively employed in evaluating legal rules. That is, legal rules should be selected entirely with respect to their effects on the well-being of individuals in society (Tilley, 2017).

6.5.1 *Governmental, technical and institutional recommendations*

1. The government support for CC adaptation management in Nigeria as a whole is very weak. This research, therefore, recommends a comprehensive review of all governmental aspects connecting to CC management in the community. The review should reinforce, harmonize and accord with Article 6 of the 1992 United Nations Framework Convention on CC. This calls for parties to promote and facilitate "*public participation in addressing CC and its effects and developing adequate responses*" (UNFCCC, 1992, p. 17).

2. Many operating challenges limiting sustainable CC impact management in the study area are traceable to the absence of a comprehensive adaptation strategy document for the management of CC impacts in the State. It is important to have a plan urgently stating realistic targets for the reduction of climate impacts on a long-term basis and better managing them. Impact reduction strategies should ensure all buildings have adequate drainage.

3. Although the Federal Government has recognized the need to act in response to CC impacts to achieve results, it has not drawn up a strategy or gathered sufficient data on the real state of impacts. To overcome this situation, further research on CC impacts is needed to measure and estimate impacts as a start to combating it.

4. All decision-makers within national, state, local governments and institutions, both public and private, should recognize their exposure to CC impacts and options for adapting to reduce impacts.

5. The Executive branch of the Federal Ministry of the Environment should initiate the development of joint efforts with local community leaders and share strategies to form a National Adaptation Plan.

6. Adaptation policy and strategy to be implemented by state and local government should be initiated by the Federal Government. This is because adaptation applications are more

effective on smaller scales. A bottom-up approach will be specific to the needs of individual communities.

7. Adding adaptation and mitigation intentions into procedures, budgets and planning processes and programmes of cities and other local governments and designing sustained awareness programmes on CC impacts across churches, mosques, schools and other community groups.

6.5.2 *Operational and socio-economic recommendations*

1. The private sector and the public at large should evaluate their vulnerabilities and threats and proactively engage and partner with the relevant legislative adaptation planning efforts to help national adaptation capacity.

2. Conduct financial valuations of likely adaptation associated infrastructure needs and operating costs and appraisal of the possible impact of adaptation on revenue.

3. Adaptation objectives should be combined into current government programmes and policies that have international components. These include agriculture, trade policies, energy policy, transportation policy, international aid, disaster relief and national security.

6.6 Recommendations for further studies

Based on the outcomes of this study, some recommendations are identified to offer direction for future research.

1. To research on the level of national government's engagement with communities on existing strategies on the CC adaption of communities, with the aim of building awareness on the scale of adaptation and reasons for adaptation.

2. Further research on the exact cost of kerosene fuel used for lighting may prove enlightening for communities that still depend on kerosene lamps for lighting, even in the day.

3. It would be of value to replicate this research in other communities for comparative analysis.

4. To investigate why there is a significant shift in the maintenance frequency of 'Ate' foundations in relation to water, even though rainfall patterns have not changed over the past 30 years.

CHAPTER 7 : REFERENCES

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CHAPTER 8 : APPENDICES

8.1 Appendix 1: Blank copy of survey questionnaire

School of Architecture and Built Environment
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West Midlands
United Kingdom.

Cost Benefit Analysis of Climate Change Adaptation of the *Tiv* traditional hut (*Ate*): *A Case Study of the Kanshio Community, Makurdi. Benue State, Nigeria.*

2015 Research project by
Ohiaeri Mvande B
Registration Number: [redacted]
This questionnaire is designed by a Research student from the University of Wolverhampton. The questionnaire is intended to collect information about the cost and benefit of adapting the *Tiv* Traditional building 'Ate' to climate change impacts.

Participating in the exercise is voluntary and participants may opt out at any point. Participants are also free to skip questions they do not wish to answer. The questionnaire will take **less than 10 minutes to complete**.

All information given by participants will be confidential. The questionnaire will be administered and collected on the spot, however, if participants decide to return it later, it can be sent directly to this email: [redacted]

Section A: Personal Background

1. Gender of respondent.

Female ☐ Male ☐ Others ☐

2. What age group do you belong to?

18-29 ☐ 30-45 ☐ 44-60 ☐ above 60 ☐

3. What is your ethnicity?

Tiv ☐ Idoma ☐ Igede ☐ Etilo ☐ Other ☐ Specify ....

4. What is your occupation?

Civil servant ☐ Builder ☐ Farmer ☐ Business man ☐ Other Specify......

5. Contact telephone number/e-mail (*optional)* ☐

Section B. House information

6. Do you own a hut (*Ate*)? Yes ☐ No ☐

7. Have you ever participated in building an *Ate*? Yes ☐ No ☐

8. How old is the *Ate*?

1-5 years ☐ 6-10 years ☐ 11-15 years ☐ 6-20 years ☐ above 20 years ☐

9. Approximately how much did it cost to build the *Ate*?

₦ 11,000-20,000 ☐ ₦ 21,000-30,000 ☐ ₦ 31,000-40,000 ☐ ₦ 41,000- 51,000 ☐

₦ 51,000-60,000 ☐ Specify others......

10. Who built your hut (*Ate*)?

Family and Friends ☐ Yourself ☐ Professional Builders ☐ Others Specify......................

Section C. Building Material and Maintenance

11. Which of the following building materials did you use? *Please tick all that apply.*

Earth ☐ Stones ☐ Bamboo ☐ Straw ☐ Grass ☐ Others Specify ......

12. Have you ever renovated/repaired your house? Yes ☐ No ☐

13. What feature(s) did you renovate? *Please tick all that apply*

Roof structure ☐ External walls ☐ Roof straw ☐ Doors ☐

Foundation ☐ Room floor ☐ Specify others.............

14. What stirred the renovation?

Flood ☐ Cracks ☐ Rain ☐ Temperature variation ☐ others Specify ....

15. How often did you have to renovate this aspect of the Ate?

Yearly ☐ Once in two years ☐ Once in four years ☐ Once in 8 years

Once in 10 years and above ☐

16. Has the frequency for the need of renovation changed?

Quarterly ☐ Yearly ☐ Once in two years ☐ Once in four years

Once in 8 Years ☐

17. What weather condition(s) impacts on your hut (*Ate*) most?

Rain ☐ Temperature ☐ Flood ☐ Specify others.........

18. What are you doing to reduce or stop the impacts?

Please specify ☐

19. What is the main source of light for your hut (*Ate*) in the day time?

Electricity ☐ Daylight ☐ Kerosene Lamps ☐ Generator ☐

20. What is the main source of light for your hut (*Ate*) at night time?

Electricity ☐ Kerosene lamps ☐ Generator ☐ Solar power ☐

Specify others……………..

21. Please provide any other suggestions on how the *Ate* could be better adapted to environmental impacts.

22. If you would want to be contacted for further discussions regarding this survey please tick the box ☐

Thank you for your time and assistance.

8.2 Appendix 2: Historic temperature, rainfall and humidity data

Appendix 2 — Historic, Temperature Rainfall and Humidity data

MAKURDI TOTAL MONTHLY RAINFALL (1990 - 2016) UNIT: mm

YEAR	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Jan	0	0	4.4	0	27.1	0	0	0	0	1	0	0	0	0
Feb	0	0	3.1	0	0	4.4	0.1	0	0	0	0	0	0	0
Mar	0	45.8	5.2	9.2	0	15.4	0	1.5	0	42.2	0	0	42.4	0
Apr	109.9	103.9	65.3	46.9	58.7	35.1	109.2	204.5	134.8	112.3	96.4	98.5	79	56.4
May	79.7	183.2	75	52.9	150.5	85	135.4	99.1	156.2	154.6	114.2	136.7	109.9	30.7
Jun	142.3	82.7	84.2	268.1	108.4	353.9	241	161.5	338.8	304.6	227.3	240.5	171.1	200
Jul	158.5	96.4	154.8	341.3	82	108.4	204.8	87.4	241.9	132.3	172.7	96.1	187.9	119.2
Aug	219.5	264.3	154.5	174.6	213.4	284.4	287.7	167.1	254.3	347.7	334.6	251	312.4	145.3
Sep	310.8	185	312.6	137.2	184.1	119.3	247	377.2	318	367.3	149.2	216.3	262	136.4
Oct	81.2	161.2	80.9	186.9	149	154.1	98.7	235.8	93.6	155.1	79	36.9	108.5	39.8
Nov	1.6	0	32.7	0	0	12.1	0	27.2	0	0	0	0	0	33.7
Dec	17.4	0	0	0	0	0	0	0	0	0	0	0	0	0

MAKURDI MONTHLY MAXIMUM TEMPERATURE (1990 - 2016) UNIT: Deg. Celsius

YEAR	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Jan	35.7	35.0	34.0	33.7	34.4	34.7	36.6	35.7	35.2	35.7	35.9	35.7	34.3	35.7
Feb	37.1	37.6	37.2	37.1	36.6	37.3	37.6	36.3	39.0	37.1	35.9	36.8	37.3	37.6
Mar	39.5	37.2	36.4	36.9	38.5	37.8	37.1	37.1	38.8	37.2	38.4	38.2	37.6	38.5
Apr	36.0	34.7	35.9	36.2	35.5	36.2	35.3	33.5	37.0	35.6	36.3	35.8	34.5	35.7
May	33.3	32.2	33.2	34.6	33.0	33.8	33.2	32.0	34.2	32.4	33.4	33.5	33.6	35.5
Jun	31.2	31.7	31.0	31.6	31.4	31.4	31.5	30.9	31.4	32.3	30.7	31.3	31.8	30.6
Jul	30.0	30.7	30.0	30.1	30.8	30.4	30.3	30.7	30.9	30.4	29.8	30.3	30.7	30.7
Aug	29.8	30.2	29.9	30.3	29.9	30.3	29.6	30.5	30.0	30.1	30.2	29.7	29.8	30.5
Sep	30.5	30.9	30.4	31.2	30.8	31.1	30.5	31.4	31.0	30.5	30.8	29.9	30.3	30.8
Oct	31.9	31.0	31.5	32.1	31.5	32.2	31.5	32.4	32.5	31.4	31.9	32.1	31.5	32.8
Nov	33.3	33.7	32.6	33.8	33.6	33.7	34.2	33.4	35.0	33.7	35.0	34.8	33.8	34.4
Dec	33.7	33.6	34.4	34.6	34.2	35.1	35.3	34.2	34.9	34.7	34.9	35.9	34.9	34.7

MAKURDI MONTHLY MINIMUM TEMPERATURE (1990 - 2016) UNIT: Deg. Celsius

YEAR	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Jan	20.0	18.0	18.2	18.4	20.8	18.0	18.5	20.6	18.4	20.4	20.2	16.5	18.2	19.6
Feb	20.8	24.4	19.2	21.8	21.5	21.0	25.1	18.7	23.8	25.3	20.7	20.4	22.0	23.5
Mar	22.8	25.7	24.9	24.7	26.4	26.0	25.9	25.2	25.1	26.1	22.8	26.4	26.4	26.3
Apr	25.9	24.9	25.8	25.5	25.1	25.7	25.3	24.2	26.3	25.3	25.6	25.0	25.2	25.8
May	24.0	24.0	24.4	24.6	24.2	24.3	24.1	23.6	25.0	23.8	24.5	24.0	24.5	25.6
Jun	22.9	23.8	23.3	23.4	23.5	23.2	23.4	23.0	23.6	23.5	22.3	23.3	23.3	23.2
Jul	23.0	23.2	23.0	22.5	23.2	23.2	22.6	23.5	23.7	23.0	22.9	23.4	23.1	23.4
Aug	22.8	23.2	23.2	22.8	23.1	22.9	22.6	23.1	23.1	23.0	22.4	23.0	23.1	23.6
Sep	22.6	22.6	22.6	22.6	23.0	23.1	22.9	22.8	23.3	22.5	22.7	22.6	22.5	22.8
Oct	22.9	22.5	22.6	22.7	22.5	23.5	22.4	23.4	23.4	22.6	23.3	22.6	22.0	23.5
Nov	22.7	20.6	20.1	23.1	19.7	18.6	17.5	23.3	22.1	22.4	21.5	20.6	19.9	21.2
Dec	22.4	16.7	16.0	17.9	15.6	17.1	16.2	17.2	19.1	16.2	17.5	18.0	17.4	17.4

MAKURDI MONTHLY RELATIVE HUMIDITY (1990 - 2016) UNIT: Percentage (%)

YEAR	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Jan	46	39	39	47	37	51	47	44	46	54	42	47	49	45
Feb	58	38	45	42	37	53	30	43	57	34	42	46	53	41
Mar	60	61	54	55	58	60	51	43	61	44	59	59	48	51
Apr	71	65	65	65	64	67	64	64	65	63	67	71	66	76
May	77	75	71	73	71	75	76	73	75	74	74	73	67	73
Jun	79	78	77	77	77	79	80	80	75	80	78	77	79	78
Jul	79	80	81	72	79	80	79	82	80	81	80	81	81	81
Aug	83	82	81	82	82	82	79	84	81	81	82	81	82	83
Sep	82	82	78	81	78	81	80	80	80	81	81	82	82	82
Oct	80	79	78	79	77	77	77	77	78	78	75	77	78	79
Nov	68	68	73	62	61	60	74	68	70	67	65	67	69	70
Dec	51	56	52	39	55	54	53	52	50	49	56	74	51	59

2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
0	0	46.9	0	3	2.3	0	0	0	0	4	0	0.0
0	0	0	0	0	0	0	68.8	0.5	0	4	111.8	0.0
7.8	22	13.3	8.7	0	3	12.6	0	0	44.2	25.6	3.9	52.6
61	42.9	26.1	124.8	94.4	180.1	31.4	78	143.2	113.2	56.4	14	91.6
73.3	90.5	276.1	170.5	147.4	196.3	133.1	141.6	139.5	199	158.7	37.2	233.2
164.5	209.8	109.9	210	186.1	239.6	113.2	91.2	160.6	141.8	165	151.6	50.9
169.8	142.4	322.7	114.5	81.6	85.1	196.9	87	297.9	243.6	128	128	265.2
185.1	112.7	215.1	272.7	280.2	275.3	178.1	224.6	174.3	134.9	134.9	134.9	214.0
147.9	159.4	229.3	217.9	83	140.5	335.5	272	290.7	282.9	282.9	282.9	268.9
147.5	91.6	103.6	219.2	84.5	284.1	121.3	174.8	232.7	174.8	125.5	82.9	116.1
0.7	0	0	1.6	0	1.2	24	0	27.3	0	0	16.8	0.0
0	0	0	0	1.6	0	0	0	0	0	10.1	10.1	0.0

2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
35.5	34.3	36.2	34.5	33.0	35.5	36.3	34.6	34.6	35.4	35.5	33.8	33.9
37.7	38.3	36.4	37.9	36.8	37.3	38.4	35.4	35.9	36.7	37.0	35.9	35.8
37.9	38.1	37.0	38.2	37.6	38.2	38.5	37.1	38.2	37.7	36.2	35.8	37.7
35.9	37.8	37.9	35.2	34.9	35.0	37.7	35.3	35.1	34.4	35.2	35.6	36.6
33.5	33.4	32.4	32.5	32.4	32.7	34.0	33.1	31.9	32.2	33.1	35.0	32.1
31.4	31.3	31.8	31.3	31.1	31.8	31.3	31.1	30.6	31.0	31.6	32.6	30.8
30.5	30.6	30.8	31.2	30.5	30.8	30.2	30.7	29.8	30.0	30.6	30.6	30.1
30.0	30.1	30.1	29.7	29.9	30.5	30.3	29.5	29.4	29.4	29.4	29.4	29.9
30.7	31.0	30.4	30.4	31.1	31.0	30.5	30.4	30.3	30.3	30.3	30.3	30.4
32.0	32.3	32.2	31.7	32.6	30.8	31.8	30.8	31.1	31.9	31.9	32.4	31.8
34.0	34.9	34.0	33.4	34.7	33.4	33.6	34.0	33.4	34.3	33.4	34.1	34.3
35.2	35.2	34.9	34.9	35.1	35.5	34.8	34.5	34.4	34.6	34.6	33.3	34.3

2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
20.0	19.0	23.2	18.3	18.6	22.0	18.6	16.5	18.3	17.9	18.3	17.9	15.6
22.1	25.5	25.0	22.5	20.4	24.9	25.7	24.3	22.8	20.9	21.3	23.7	20.0
25.1	26.9	26.3	24.9	26.3	25.7	26.2	26.1	23.5	23.3	24.2	24.2	25.4
25.5	26.8	26.9	25.0	24.8	24.3	26.4	24.9	22.8	21.5	23.1	24.0	25.8
24.5	24.7	22.8	24.0	23.8	23.0	24.7	24.1	21.4	20.4	22.3	24.4	23.6
23.5	23.7	23.5	23.8	21.9	22.0	23.9	22.6	21.1	20.5	21.6	23.6	23.0
23.1	23.5	23.6	23.9	23.4	22.2	23.2	22.0	20.6	22.6	21.9	21.7	22.5
23.3	23.6	23.2	23.2	23.2	22.6	23.5	22.3	20.6	22.7	22.7	22.7	22.8
22.7	23.3	23.0	22.7	23.5	22.9	23.0	21.9	20.5	22.4	22.4	22.4	22.5
23.2	23.3	23.4	22.9	23.5	22.6	23.1	21.6	20.4	23.0	23.0	23.8	22.5
22.4	20.1	19.3	22.8	21.8	20.8	23.1	19.4	20.7	23.0	21.3	20.1	20.0
17.5	19.6	14.9	17.8	20.4	15.6	16.0	14.5	15.5	19.5	19.5	17.6	15.4

2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
38	62	34	42	56	46	41	28	45	46	50	35	53
58	60	47	70	58	49	46	59	57	54	42	36	35
59	62	52	77	58	47	43	54	61	55	58	56	39
62	60	68	81	70	62	55	61	68	56	66	47	65
75	79	80	82	78	72	68	70	75	65	75	77	73
82	80	81	84	81	75	75	76	75	78	76	80	78
82	83	80	81	82	77	79	76	82	80	88	80	81
82	83	85	78	84	79	80	80	82	82	84	83	83
81	84	83	67	82	76	78	78	79	81	82	81	81
77	79	80	61	82	76	74	76	79	78	77	77	77
65	63	74	65	67	56	66	55	69	66	66	64	73
60	50	59	54	56	42	40	44	48	55	56	54	70

8.3 Appendix 3: List of publications

A Review of the Impact of Climate Change on the Built Environment of Rural Tropical Regions: *International Workshop on Earthquake and Sustainable Materials* (IWESM) Anadolu University Turkey, Porsuk Vocational School, 24 June 2014, pp. 236-249.

Evaluation of African Traditional Architecture from a Sustainable Perspective: Case Study of "Ate Tiv". *Abstracts of Fifth International Conference on Climate Change Adaptation, Toronto Canada*. October 2016, pp. 25.

Adaptation Options for Tropical Rural Communities: A Case Study of Kanshio, Benue State, Nigeria *https://www.intechopen.com/books/isbs-2019-4th-international-sustainable-buildings-symposium/isbs-2019-4th-international-sustainable-buildings-symposium* 30 October 30 2019, pp. 547-557.

8.4 Appendix 4: An Example of an Ate hut used in the questionnaire